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THE SOONKÊSALA CANAL.

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I.

The object of this paper is to give a general description of the canal between Soonkêsala and Cuddapah, recently constructed for irrigation and navigation by the Madras Irrigation and Canal Company; and also to direct particular attention to the mode of safely constructing high banks for canals or tanks, illustrated by that work.

It seems not to admit of doubt, that the countries possessing the greatest powers of production are those in which the yearly rainfall is concentrated into a few months; as it is certainly beyond doubt that the innate resources of such countries are up to this time the least developed. Settled warm weather is the safest for crops at every stage of their sprouting, growth, and ripening; and, not only in England but in India, it is found that crops grown during uncertain weather, as all unirrigated crops must be, are nearly as often and as severely injured by rains or floods as by drought. Egypt, as far back as history exists, has been a country of settled weather, and also notorious for its fertility; yet that country, even as far as irrigation has gone, can scarcely be called more than half developed. To fully develop the productive powers of land three things are needed: first, settled weather, which art cannot give nor control, and can only turn to account; secondly, irrigation, which must be controlled by art, though a supply must exist upon which art may operate; and, lastly, manure. When it is considered that good land, under constant cultivation in a settled climate, may utilize a ton of guano an acre a year, besides more bulky and less potent manures, it is impossible not to think what a population the world is capable of supporting, and how unnecessary it is that so many mouths in the most industrious nations are insufficiently filled.

From time immemorial the native inhabitants of the Madras Presidency have spent large sums in the construction and management of undertakings having for their object the application of water to irrigate fields and gardens. The only native engineering buildings in the country consist of works of irrigation, fortification, religious worship, and shelter for travelers; and of these, in magnitude and importance, works of irrigation rank the first. These have been of three chief kinds, viz.:

I. Wells, which are generally large

square pits lined with stone, from which water is raised by simple machinery and delivered on to the fields.

II. Tanks or reservoirs, which are filled by rain-water, and from which the water flows through sluices on to the fields.

III. River channels, of which the canal under review is one. These are the most prized of all the methods, and are stated to give twenty-five per cent. more crop per acre than either wells or tanks. In some few cases tanks were supplied from river channels, as at Nundloor, Nellore, &c.

River channels were constructed for turning the water of rivers on to the fields in such a way that a nearly constant supply should flow down them, whenever floods should come down the river. Unless so constructed they required to be annually closed, near their entrance or offtake from the river, by a bank; for head sluices were rarely made. The first object, viz., an offtake of constant supply, is accomplished in various ways. If the river bed be a broad ill-defined one of deep sand, channels are cut parallel to the river along its margin, having their bed lower than the summer level of the water in the sandy river bed, the spoil being thrown towards the river to make a flood bank, and prevent the river floods flowing into the channel. The upstream end of this flood bank would abut upon any natural sandhill or other eminence. After running down a mile or two, the channel is given a less fall than the river, and is gradually brought out of the river bed. Such channels flow by filtration, whether the river be quite dry or in full fresh. They are numerous on the rivers Chêyêr and Chittrawutty. On the other hand, if the river bed be rock, a constant offtake may be secured by carrying a rough weir of loose stones across the rocky bed of the river, and returning it downwards under each bank in the margin of the river bed, until out of the reach of floods; as at Hoossoor, Darojee, &c. The upper side of each return forms the inside of the channel, and is well lined with earth and vegetation. The weir and returns have their crests all at the same level; and the channel runs with a slight fall from the ends of each return.

Where the formation of the ground is such that a channel of the former sort in a sandy river would be carried away yearly, the side channel is abandoned, and the offtake channel requires to be banked across its mouth yearly to prevent the floods running down it and doing damage. This can be conveniently done at the close of the dry season; and when the rains are over and irrigation is needed, the entrance is cleared and a catch bank of sand is constructed in the river bed to divert the water of the river into the channel. This catch bank is run farther and farther out upward across the stream as the river falls, and at an angle of about 30° with the direction of the stream, so as to keep the supply to the channel constant, until the bank may perhaps extend right across the river. Similarly, where the formation of the ground is such that a weir in a rocky river cannot be returned along the rocky river bank, the channel has been run directly from the end of the weir and at once completely banked off from the river. The case or cases of head sluices being built to such channels before the English rule are so few that it can be hardly called Hindoo practice to build them at all, so far as the author's personal experience goes. To prevent excessive damage from the river floods, the entrances of such channels are generally cut very narrow, and, if possible, in solid rock; and numerous waste weirs are placed along the channel in the course of the first mile or two in order to get rid of the surplus water poured in by floods through this narrow entrance.

English engineers soon adopted the rule of placing head sluices across all river channels at or near their entrance. They also extended the use of weirs to sandy rivers as well as to rocky ones, as more effective than the annual bank of sand. Scouring sluices were inserted (not always judiciously) in the weirs, to keep down the silt in the pond above them, and to clear the face of the head sluices of the channels led off from the pond. These scouring sluices are invariably in Madras called "undersluices," whether in the weir or not, though, in the latter case, no water goes over them. Indeed, none of the so-called "undersluices" of the Madras Irrigation and Canal Company are strictly undersluices, but they are merely low-level scouring sluices

built at the end of the weir, and generally in a line with it.

By great energy some of the engineers of the Madras army induced the Madras Government tentatively to adopt these innovations in situations admirably chosen for the trial; and weirs were constructed at the head of all the considerable deltas—as the Cauvery, Kristna and Godavery—of rivers having a sufficiently constant flow to irrigate fields for one crop at least of rice each year. The channels from these weirs run along the uniform slope of the delta country, rarely crossing any considerable drainage, and diverge like the rays of a fan from each end of the weir.

The first result of the great success of these innovations was the extended use of similar permanent weirs at the heads of channels, for rivers of very short and uncertain flow, which, instead of running to the fields, run into a series of ordinary village tanks. Of such a kind is the Nellore Anicut across the Penner. By its means the floods of the Penner are distributed; but, as in London, each householder, so in Nellore, each village, irrigated by the weir, has to provide and keep in repair its own tank to receive and store the intermittent supply, as well as an escape weir for the passage of surplus water to the next tank below. These tanks rarely exceed one mile in breadth and nine feet in depth of water. Other rivers have received, as the Palâr, &c., or deserve, as the Soonamooky, &c., similar treatment.

While the rebuilding of the Nellore Anicut, since it was last carried away, was making progress the "Toombuddra project," for using the inland rivers for irrigation, was adopted by the Secretary of State, so far that interest was guaranteed on £1,000,000 to be raised by the Madras Irrigation and Canal Company, towards carrying out a definite portion of that project for irrigation and navigation combined. The objects of the Toombuddra project, of which the Soonkesala Canal is a portion, were two: the first, continuous irrigation throughout the year of three large areas, of which the largest lies in the Bellary District, the next in the Koonder Valley, and the other in the Nellore District. The second object, apparently necessary to the success of the first, was a means of communication by canals, by which the produce of these areas could be sent to a market more cheaply than by cart or railway, more expeditiously than by cart and more securely than by railway. In order to maintain irrigation, the autumn and winter supply of the river Toombuddra itself was to be directly distributed to the fields over these areas, and the surplus autumn rainfall was to be stored in large tanks near the sources of the Toonga and Budra in the western hills, in sufficient quantity to maintain the irrigation when the river Toombuddra (Toonga-Budra) itself failed. Navigation could thus be maintained along the line of irrigated country, either in the channel used for the distribution of water or in separate canals. Navigation is particularly suited to India, both on account of its cheapness and security. Two arrangements seem necessary for security, viz., that the goods should not be transferred from one vehicle to another during the whole journey, especially where other similar goods are being similarly transferred; and that the owner or his agents should be allowed to accompany the goods in whatever vehicle they be placed, and that he should be able to do so in comfort. It is not petty pilfering, but wholesale change of large consignments of grain or cotton, of which the Indian merchants express fears and relate their experience.

This Toombuddra project is one of great importance, not only for India but generally, on account of the hitherto insurmountable difficulties it is intended to meet. These are three in number. In the first place, it proposes, by the mere offer of water, to induce a vast population of ill-educated and poor ryots or cultivators to forsake in great measure the cultivation of dry grain—the only cultivation they know either by experience or tradition—and to undertake a more expensive and intelligent system of agriculture. No doubt, wherever water has already been used from time immemorial, as in the delta countries or in Scinde, it is highly prized; and additional security or extension of the supply is there immediately taken advantage of by the ryots, if the terms suit them. But in the parts of Bellary, Kurnool, and Cuddapah proposed to be supplied with water by this project, it is not so

much the extension, as the introduction of wet cultivation that is aimed at; not the irrigation of dry crops of corn, as on the Ganges and Jumna Canals, but the superseding of dry crops by wet, and that without any of the compulsion inseparable from Government works.

A second difficulty is the necessity for the provision of a constant supply of water, by storing it in sufficient quantity for all the work, for use in the dry months. For this purpose it will be necessary to construct tanks or reservoirs, having banks as high as, and longer than, any constructed in historic times, and to provide these reservoirs with surplus weirs or sluices, which on account of the great uncertainty of rain in India, and the great range through which the yearly discharge varies, will need to be of extraordinary discharging power.

The third difficulty lies in the adverse character of the country. Throughout its whole length the Toombuddra valley is crossed by ridges of hills, which render it difficult to carry off channels from the river. Hence the canals executed or projected by the Company have some very heavy cutting and banking before they can be led away from the river so as to command a large area of country. The ridge of hills which crosses the Kristna valley just below the confluence of the Toombuddra and Kristna, is about twenty-five miles wide, and its summits are nearly 3,000 feet high. The river passes through this ridge in a narrow and sinuous course, between high and often precipitous banks, for a distance of upwards of sixty miles. Neither navigation nor irrigation could be carried through such an obstruction. Instead of being surmounted, the flank of the ridge is turned by a canal on the level of the watershed dividing the Toombuddra basin from that of the Penner, which flows into the sea at Nellore. The canal already completed has its off-take from the Toombuddra, at Soonkesala, seventeen miles above Kurnool, and after a tortuous course of seventy-five miles, in which it passes over the river Hindry and three other considerable tributaries of the Toombuddra, at an average cost of £8,000 a mile, arrives near Metacondal, at the watershed between the river Boanassey, a tributary of the Kristna, and the Kali or Caulee, a branch of the Koonder, a tributary of the independent river Penner. There can hardly exist a valley more favorable for irrigation than the Koonder. The soil is good, the valley broad and flat, and the disposition of the levels, or slope of the ground, excellent. Indeed, when once the Metacondal watershed is passed, irrigation becomes almost as easy as it is from the weir at the head of a delta country, and the cost of the canal was, for the rest of its course, only £2,900 a mile.

To pass on to a description of the canal itself. The Toombuddra project was first brought forward by Colonel Haviland, but it was not till 1858 that the Madras Government, on the report of General Sir Arthur Cotton, and other engineers, selected it as the first work to be undertaken by the Madras Irrigation and Canal Company. In 1861 that Government limited the work of construction under the guarantee to the canal between Soonkesala and Cuddapah, and the weir at Someshwaram; and in 1866 made terms with the Company for completing the canal between Kurnool and Cuddapah by the 1st July, 1871.

The character of the canal may be sketched as follows: the first seventy-five miles is calculated to carry 400,000 cubic yards of water per hour at the head at Soonkesala, and, after gradually parting with about 100,000 cubic yards for irrigation, to convey at least 300,000 cubic yards an hour through the Metacondal cutting at its other extremity. There 255,000 cubic yards an hour may be discharged into the Kali, and 45,000 cubic yards carried down the continuation of the canal. Of the 255,000 cubic yards an hour poured into the Kali, the canal is calculated to take up 100,000 cubic yards at Jutoor and 50,000 cubic yards at Rajoli, leaving above 100,000 cubic yards of water per hour for the insignificant irrigation below Cuddapah and for Nellore.

The canal begins at Soonkesala with a weir, Figs. 3 and 4, across the river Toombuddra, 1,500 yards in total length of clear over-fall, which is broken into two lengths by an intervening island. The weir stands upon the rocky river bed, and is formed of three patterns, viz.: 1. Of solid rubble masonry of gneiss, trap and quartzite boulders, of

the form Fig. 3. 2. Of gravel concrete, with gneiss rubble facing in front and rear, of the same section. 3. All recent portions are of solid gneiss rubble masonry, with a facing on the lower side of

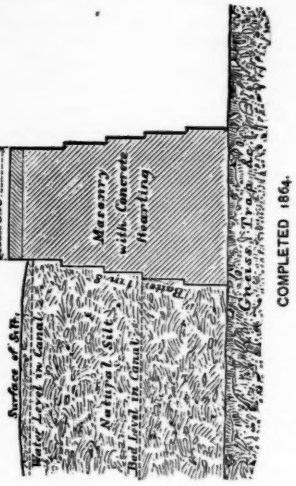
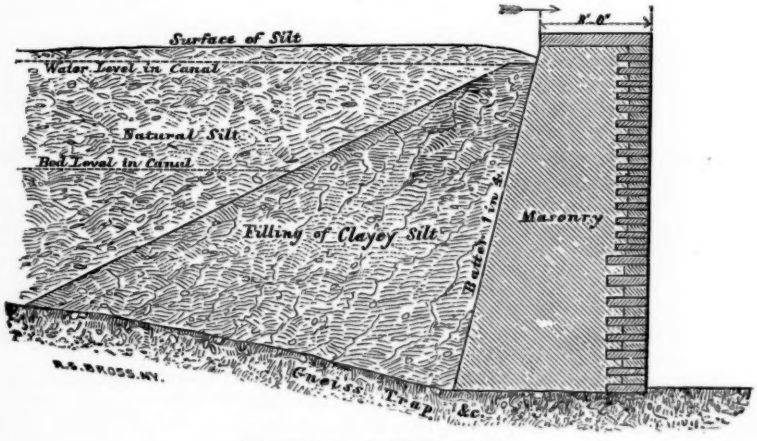


Fig. 3.

Kurnool limestone ashlar, which averages ¾ yard thick where exposed to concussion. Fig. 4. Patterns Nos. 1 and 2 have a front and rear batter of 1 in 8; while No. 3 has an upper batter of 1 in 4, and a rear face vertical. All are eight feet broad at the top, and coped with dressed limestones one foot thick, of which every alternate one is a through stone eight feet long, weighing about 1½ tons. The mortar throughout is of Kurnool kunkur, except the joints of the coping, which are of Portland cement. The coping is joggled wherever the anicut (which is not straight, but follows the line of highest solid rock) is concave in plan on the up-stream side. No part of the anicut formed on any of the above patterns, either with or without the coping, has ever failed. The height varies from six feet to twenty-six feet, and averages about eighteen feet; and the highest registered flood rose 7½ feet over the crest.

From the pond above the Soonkesala weir the water is admitted into the canal by a head sluice without any lock. The face of the head sluice is kept clear by the scour of ten undersluices at a lower level in the weir, the stream to which is forced against the front of the head sluices by a long curvilinear groin. The minimum cross-section of the canal for the first seventy-five miles has a ninety-

Fig. 4.



SOONKESALA WEIR, COMPLETED 1869.

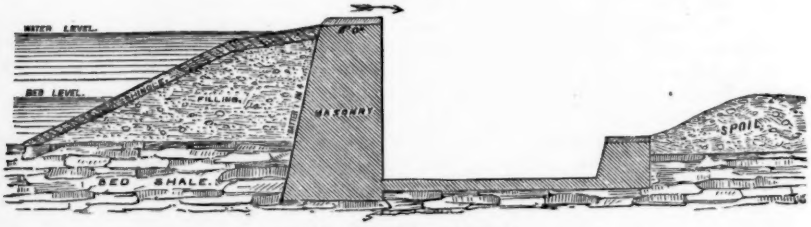
feet bottom, with two to one side slopes. For the first forty-five miles the fall per mile is adapted to secure a discharge of 400,000 cubic yards of water an hour, if requisite, without increasing the depth of the water to more than eight feet. Below the forty-fifth mile, the canal being in good soil, and lying on easy slopes

with limestone or shale subsoil, a depth of nine feet of water is allowed. At the seventy-fifth mile, the canal passes through the watershed between the Toombuddra and the Penner rivers; and thence the natural water-course becomes the main supply channel, under the successive names of the Kali, the Koonder, and the Penner. From this natural main supply channel the water is taken at four points, viz., Lockinsula, Jutoor, Rajoli, and Adanimayapilly, by the simple process of throwing weirs across it, with undersluices in the weirs to keep down the silt, and head sluices across the channel to control the supply and entrance locks.

The first branch irrigating channel forms the main canal from the seventy-fifth to the ninety-fifth mile. Its head is formed at Lockinsula by blocking up the water-course (there so rudimentary as to have been used for a village road) by a bank with scouring sluices, and turning the main supply over a natural weir of rock, whence it joins the old water-course below. The head sluice and lock are adapted for working this branch with a depth of six feet of water, when the irrigation becomes sufficiently extended to require it in the Nundi-cotacoor and Nundial Talooks, and at this depth the flow will be 45,000 cubic yards an hour. This canal is an irrigating channel for the first six miles only. Below that it is a still-water canal, with a fall of 180 feet 5 inches, overcome by seven double-chambered locks and five single-chambered locks. The greatest drop in any one double lock is 21 feet 8 inches, and in a single lock 13 feet. The chambers are 120 feet long, by 20 feet broad. The canal is forty-five feet wide at the bottom, and the minimum depth is five feet.

The second branch irrigating channel takes its supply from the main stream in the Kali at Jutoor, and forms the main canal from the 95th to the 146th mile. It has a very wide area of distribution in the Nundial, Seriwell, and Koilcoontla Talooks of the Kurnool district. It is intended to distribute 130,000 cubic yards of water an hour, if required; but to do this two feet height must be added to the banks over the first twenty miles of its course. In its present form it is adapted for carrying about 100,000 cubic yards an hour; and this is probably enough to supply rice for all the local demand for food, leaving the cultivation of cotton and indigo, for which the valley is celebrated, more room than is available while dry grain has to be grown for food. Already the Company has irrigated a greater area of dry than wet crop in this valley. A good indigo crop is of more value as an article of commerce than a good rice crop, but hitherto indigo cultivation has been so precarious that a really good crop might not be obtained once in six years. No crop more needs and repays irrigation. The head works consist of a weir (Fig. 5)

FIG. 5.



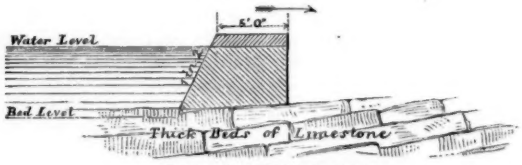
JUTON WEIR, COMPLETED 1869.

of solid limestone in rubble masonry founded on soft shale, and of head sluices, the face of which are scoured by undersluices in the weir by help of a training wall and of an entrance lock. The weir is six feet broad below the coping, and has a batter on the upper side of one in four; the rear face, which is ashlar, descends vertically into a trench or water cushion, hollowed out of the shale and lined with limestone masonry. This water cushion is narrower than it should be. The coping is protected from floating timber by a foreshore of

rubbish from the shale excavation. This branch is adapted for a depth of six feet of water down to the first drop lock in the 118th mile. Below that lock, water is passed, for a limited extent of irrigation, round ten locks, and at the eleventh lock (130th mile) all irrigation ceases. The canal between the 118th and the 146th mile consists of level reaches adapted for a depth of five feet of water, and contains seventeen locks, with a total fall of 187 feet 6 inches, and a maximum fall in any one of fourteen feet. The bottom breadth throughout is fifty feet.

The third branch irrigating channel takes its supply from the main stream in the Koonder at Rajoli. The 146th mile of the navigable canal falls into this branch about one-fourth mile below its head, and is continued to the 180th mile. The Rajoli weir is of solid limestone in coursed rubble masonry, five feet thick at the top, with a batter of one in two on the upper face and plumb on the lower face. (Fig. 6). It stands on thick beds of solid limestone. With a depth of five feet of water in it, the canal will discharge 50,000 cubic yards of water an hour, the bottom breadth being fifty

FIG. 6.



RAJOLI WEIR, COMPLETED 1869.

feet. The irrigating channel ceases at the first lock in the 172d mile, and thence to the river Penner is a still-water canal, which falls ninety feet six inches, by means of nine locks, of which the greatest drop is thirteen feet.

The fourth branch is a length of eight miles of canal at nearly a level, supplying a small area of irrigation. It is, in fact, the first eight miles of the projected continuation of the canal into Nellore. It is adapted to distribute for irrigation about 5,000 cubic yards an hour of water, and has a bottom breadth of fifty feet. The headworks consist of a weir across the main supply in the Penner, with head and under sluices, and entrance lock. The river gates of the entrance lock are twenty-five feet high, and are the heaviest on the canal. The weir for a short portion of its length is of solid limestone in rubble masonry founded on rock; but the greater proportion of it is founded on sand, and consists of a masonry slope supported on the upper edge by a double row of wells and on the lower edge by a single row of deep wells. There is a longitudinal row of wells along the middle also. The slope is 1 in 11.75; and below the slope is a dry rubble apron 105 feet broad. The canal terminates at a distance of 1½ miles from the Madras railway, and 163 miles from Madras.

Besides the weirs, some of the masonry works on the canal deserve notice. The Hindry aqueduct carries the canal ninety feet broad and eight feet deep over the Hindry, at an elevation of thirty-two feet, by fourteen forty-feet arches, the length between the abutments being 651 feet. The lowest headway, at full water, under any bridge over the canal, is fifteen feet; the smallest width, in locks is twenty feet. The under bridges have a width of thirty feet, except in two cases, where it is twenty-five feet. The lock chambers are twenty feet by 120 feet in the clear, and are adapted for working with a depth of five feet six inches of water, though they will work with less. The filling and emptying sluices are a pair to each pair of lock gates, *i. e.*, four to each single lock. Each sluice has an opening four feet square, and the ratio of the inlet ports to the sluice and to the outlet ports is as 5, 4 and 8 respectively.

The grade or fall of the canal where it is taken down the irrigating channel varies between eighteen inches a mile in one or two deep cuttings, and a level in the tanks formed where the canal is carried over an open valley, by damming it

across. In other places it is usually from four to six inches a mile. The last seems to be the most suitable fall where the cuttings and banks are of cotton soil unprotected by revetment of any sort; but it is impossible, without further experience, to say whether a more rapid fall would not be better. The more rapid the fall, the less silt will be deposited, but the more current there will be against ascending boats. Hitherto the silt has given but little trouble, and it seems likely that an annual outlay of £1,000 will suffice to remove all deposits of silt.

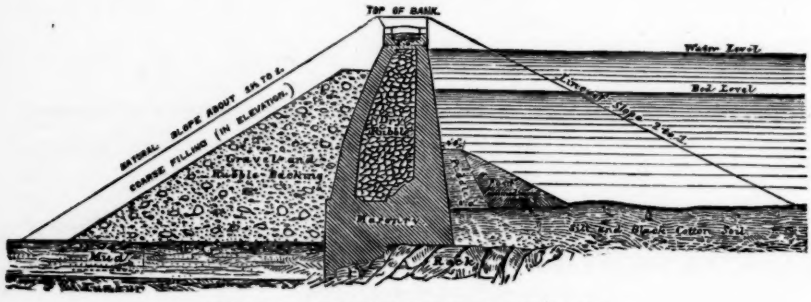
The lock sluices are simple cast-iron shutters running on wheels eight inches in diameter. When quite closed, however, the shutter bears on the cast-iron frame or seat. They are readily raised by a rack by two men in a few seconds, or by one man where balance weights are attached.

No measuring sluices are needed. Two sizes of sluices for irrigation are used, besides some small ones, closed by hand, in the first three sections. The smaller size is eighteen inches wide and one foot lift, worked by turning round a vertical screw lifting a cross-head, to which the cast-iron shutter hangs. The larger has a lift of three feet nine inches, and is five feet broad, the shutter being made of wood; and it is raised in the same way as the smaller ones. Each turn of the screw raises the shutter one inch, and one man can easily work it against an average head of water six feet. The raising gear and cast-iron grooves of the larger size cost £11 4*s.*, delivered in London on board ship, and the smaller size, including iron shutter, £5 7*s.* The lock valves with crab, shutter, and frame complete, cost £36 each; while the gates complete in place, cost about £2 11*s.* per foot drop.

Though the masonry works, and especially the weirs, contain a great variety of work, the chief interest and novelty in the construction of the canal is, undoubtedly, the mode of forming the banks. These range up to a height of fifty feet from the ground surface of their site to the water line. They are upwards of thirty-five feet in total height in the 13th, 18th, 22d, 23d, for nearly half the 24th, 29th, 32d, 33d, 34th (in these last two miles one-half mile of bank is forty feet high), 48th, 54th, 58th, and 63d miles; while in the 26th and 27th miles the bank exceeds forty feet high. These banks are always on sloping ground, so that the height above the outer toe is more than the nominal height. Their formation in the above cases is as follows (in all cases the single bank is reveted or shingled on the inner slopes) :

Simple filling only in miles 5, 13, 22, 23, and part of 24, 32 40, 54, 58, 63.	
Masonry wall, Fig. 7, in miles.....	24, 26, 28.
Masonry face wall, Fig. 8, in miles.	26, 27.
Masonry revetment, Fig. 9, "	. 18.
Puddled bank, Fig. 10, "	. 24, 33, 34.
Puddle core bank, Fig. 11, "	. 26, 29.

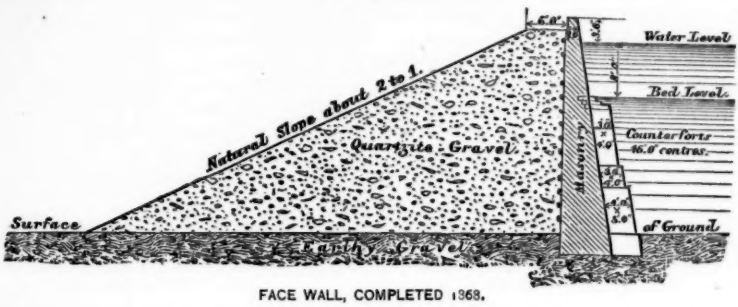
FIG. 7.



CANAL WALL, COMPLETED, EXCEPT THE PUDDLE, 1865.
PUDDLE AND WING ADDED 1871.

The banks of the sections, Figs. 7, 9 and 11, came into the author's hands in 1865, as finished works, but have since been strengthened or raised. In Fig. 7, the rear wall is almost superseded by the backing of dry rubble added behind, so

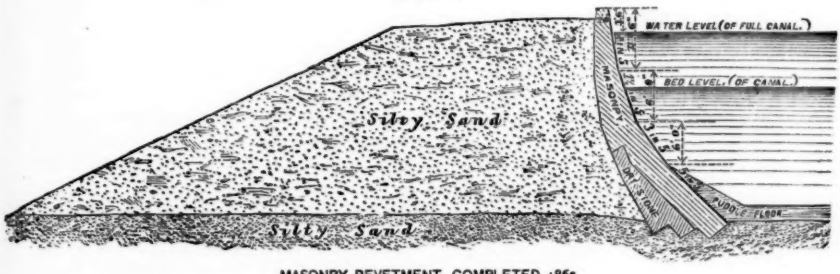
FIG. 8.



FACE WALL, COMPLETED 1868.

that the front wall acts as a face-wall to the mass of rubble behind. This is found a very efficient kind of wall; but it is right to mention that a portion of wall of this section was carried away during an extraordinary flood in August, 1870, which rose over the wall and, probably, cut down the ordinary bank at its junction with the end of the wall. The bank represented in Fig. 11 was origi-

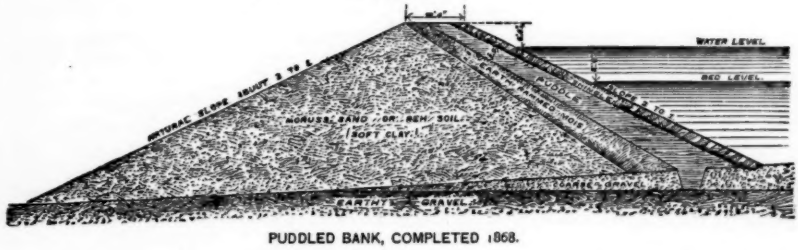
FIG. 9.



MASONRY REVETMENT, COMPLETED 1865.

nally constructed—as shown by the dotted lines—without the foreshore of puddle, and with merely a vertical central core of puddle nine feet thick, extending from top to bottom, between two slopes of hand-packed rubble. The objection to this proved to be that the vertical core, being held by the packed rubble

FIG. 10.



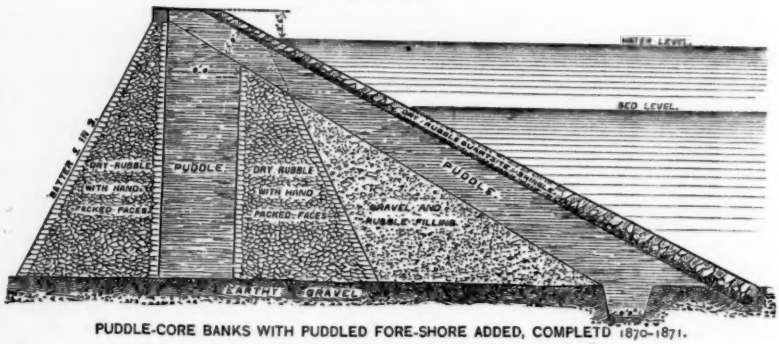
PUDDLED BANK, COMPLETED 1868.

walls, could not settle. Hence if, on first filling the canal after a dry season, the water penetrated through some crack in the core, it would extend the crack, by wearing it wider and deeper; while the puddle above would stand in an arch. No breach ever occurred from this cause, but excessive leaks took place in two cases, before the cracks could be reached through the hard puddle above them.

A puddle foreshore was therefore added, in a position more easy of access than the puddle core.

The strongest and best sections are those shown in Figs. 8 and 10; sections adopted after the experience of two seasons in the working of banks of all kinds. The author estimates the efficiency of these as so nearly equal, that the choice between them may be a question of cost. The only objection to the face-wall is that the bank cannot be raised, when once the wall is built, without carrying up the wall to a narrower width than two feet, or at least increasing the weight on the original wall by the addition of the material required to raise the bank. Hence, if enlargement of the canal be anticipated, the wall has to be built of a stouter section from the first. No portion of this face-wall has cracked or shown any signs of weakness; nor, though unprotected in front by either plaster or puddle, is the leakage more than just sensible. The puddled slopes are even tighter than the face-wall, and have proved efficient even when the bank is of the worst kind of white and gray clay, mixed with salts of lime and soda, and such as to absorb water readily. It may be thought more liable than a wall to injury from vermin, but no difficulty nor accident has yet occurred, and any defect is more readily repaired, and is less dangerous than in a wall; and this remark applies to defect from bad workmanship as well as from external violence. The total length of masonry walls in the banks is but a few chains short of five miles, and the puddled banks are nearly of the same extent.

FIG. 11.



PUDDLE-CORE BANKS WITH PUDDLED FORE-SHORE ADDED, COMPLETD 1870-1871.

In estimating the probable stability of a bank composed of soil thrown up, without either selection or puddling, when first exposed to water, a few first principles require to be borne in mind. Failure will take place either from the soil taking a flatter slope, when acted on by the water, than it originally stood at in the bank, or from leaks forming holes through the bank and ultimately destroying it. The author has successfully stopped leaks two feet six inches in diameter, occurring at a height of twelve feet above the ground; and, on the other hand, has had the rear of a bank slipping down to a slope of about one in ten also readily repaired. A little consideration will show how such casualties may be best treated; and lastly, how, by a careful construction of the bank, they may be avoided altogether.

It is necessary, in treating failures of banks, to get rid of the notion that, in practice, soil acted on by water becomes really viscous, *i. e.*, chemically semi-fluid. The action of water for all practical purposes is mechanical. It is true that the presence of salts causes dry earth rapidly to absorb water to which it may be exposed; and the subsequent deliquescence of the contained salts may leave the soil in a thoroughly boggy state. But such soil only requires mechanically draining (perhaps no easy matter) to restore it to firmness; and it will then be freed from the salt, which will have been carried away in solution. The flattest slope taken by dry material is probably that

of ground quick-lime, as it runs dry from the grindstones, when it will run nearly flat; and generally the natural slope at which dry material, deposited at haphazard, will stand, is steeper in proportion as the particles are angular and rough, and flatter in proportion as they approximate to polished spheres; in the former case hardness of each particle or piece secures a maximum steepness of slope, in the latter case a minimum. The effect of a little moisture is virtually to increase the roughness of the particles, supposing no chemical action; the cohesion of small surfaces in contact being increased so much, that if the particles are small the material may stand vertically when damp, or at an overhanging slope. Excess of water may have, however, a very different effect, which will depend on the nature of the material. Thus a mass of rubble or gravel consists of materials of such a size as to be unaffected by the presence of water, as far as regards the relative position the particles are disposed to take; except only when the flood of water is so violent as to displace them by mere force of impact. Again, clean sand may be defined as a collection of insoluble particles, so small that, though after being thoroughly wet much of the water, if allowed, will drain out of it, yet enough will remain to increase cohesion, and so much as to equal or exceed the force of gravity on any particle. But clayey earth has its particles so fine as to retain by cohesion a sufficient quantity of water to separate, or nearly separate them, and to render the mass apparently viscid; and so it will remain until the water be squeezed out by pressure or dried up by heat. It may require intense pressure or heat to render such a material really dry; but a moderate amount of either may render it very hard. When really dry, the material will have become stone, or so like stone, that the particles will not separate if again exposed to water; but if only moderately dry, as it is found in banks, it is possible that, when water is admitted into the crevices or pores of the material, it may so loosen the particles as to make them easy to separate, and unable to resist the slightest action of running water. This may happen even while the cohesion remains so strong as to check and practically resist the passage of water through the body of the material.

The two dangers of slips and leaks to which a bank is exposed, and the mode of meeting them, are the following: In the first place water may be forced by pressure into the accidental interstices or fissures in sand or clay faster than it can drain or dry out of it; as where the outer slope of a leaky bank is made of sand, or where a bank is thrown up entirely of moist clay, and the greater weight on the center squeezes out water contained in the central portion and forces it into the slopes. In both these cases slips of the slopes are likely; and they take a flatter slope than that at which they first stood. The danger from leaks is when water obtains a free passage, either through a crack or a burrow, without meeting any resistance sufficient to hold it back against the head under which it advances. The action of such a stream may enlarge the opening until the bank is destroyed. To stop a slip, either the water must be tapped by a drain before it enters the slope, or the slope must be artificially supported by a weight sufficient to prevent its movement. In the case of water flowing through a crack or burrow, no danger will result unless the material be tough clayey soil. A sandy soil soon falls in, for the bed of the cavity will absorb the water, and the material will run to so flat a slope, and the sides, right and left, will be undermined so fast, that the top will fall in from the surface of the bank before it can attain any magnitude. In a tough, loamy clay a crack is much more dangerous, for the soil is nearly impervious, and the stream will simply soften and carry away the bottom and sides of the burrow with which it comes into actual contact, and may cut its way down without widening the cavity sufficiently for it to fall in, even though it meander about and cut caverns five or six feet in diameter. The quicker the stream the more vertically the sides will stand; so that a leak of long standing is generally found to have cut a steep, narrow way nearly down to the level of the ground near the center of the bank, and then to have made a series of wide chambers on its less rapid passage to the rear. Such leaks are best stopped by filling the caverns in the rear with

gravel or rubble, and at once cutting down to the leak on the water side of the bank, and puddling it up on that side.

But the real problem is to make a bank which can neither slip nor be cut up by leaks; and may be safely filled after being dried for a couple of months by a mean daily temperature of 98° Fahr. in the shade, that of evaporation being 70°.

The consideration of this problem is the more necessary owing to the wholesale condemnation of earthen dams of above sixty-five feet in height, by M. Graeff, Engineer in Chief of the Ponts et Chaussées, in 1866. This condemnation is disproved by the long existence and security of the dam of Cumbum, 102 feet high, under ninety-four feet depth of water. It may, however, be interesting to show, that a scientific and practicable theory exists for the construction of earthen dams; and it only remains to bear in mind, that a given quality may be secured, with less risk of defective work, in earthwork, with at least as much certainty as in masonry.

Before a bank can be safely exposed to water as above, the following conditions must be satisfied:

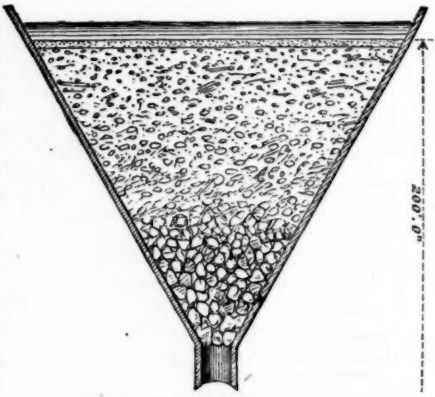
1. The greatest possible leakage must not carry any material out of the bank.
2. It must be impossible for any burrow or crack to be made right through the bank.
3. The impervious part of the bank must be secured in its place, so that neither settlement can breach it, nor leaks through cracks which will occur in it carry the material out of place.
4. The impervious part must be encouraged to settle or shrink so as to close any cracks which may occur in it.
5. It must be easy to detect and overhaul any bad puddle.

It will be found, in practice, that when a bank fulfills these conditions, the entrance of water into any part of the bank is more difficult than its exit, and that in consequence the head of water upon the bank tends to press upon and tighten up every layer of material in the bank—a result that tends very much to increase the stability of every part.

It may be well to consider first how a bank should be theoretically constructed without any puddle at all; and, for this purpose, as round numbers are convenient, a bank 200 feet high will be taken merely as an illustration. It may be observed, to start with, that though the theoretical conditions of quality and arrangement of soil may not be absolutely attainable in practice, yet the margin of safety is so large, and the modifications permissible so ample, that any condition of security can, in fact, be attained in practice. Again, it is well to premise, that not only clean sharp sand and small gravel, but also these materials, after having their interstices silted up with a tough matrix of clay or puddle, present an insurmountable obstacle to the burrowing of vermin and to cracking by heat.

Let Fig. 13 represent a vertical cross

FIG. 13.



SECTION OF A PRISMOIDAL FILTER.

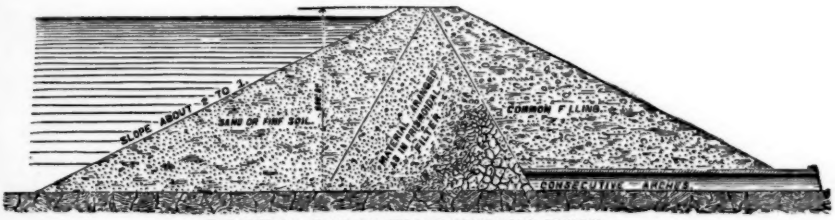
section of a perfect filter in a prismoidal or wedge-shaped trough, whose sides contain an angle of 60°. By its being perfect, let it be understood that, whatever depth of water be placed upon it, the water alone moves as it passes through the filter; and that the material of the filter is arranged in horizontal layers, beginning with fine sand at the top, and then becoming successively coarser until the lower angle contains large rubble blocks, in such accurate proportion that the water flows through freely enough not to resist that behind it, but not so freely as to leave any apertures.

If the upper layer of fine sand be as deep as the water placed upon it, and be

clean, the quantity of water flowing through the filter, or, in other words, the leakage, would be usually calculated at 700 gallons per day for each square yard of surface; which, for the filter in the figure 200 feet high, would give 13½ cubic yards of leakage an hour per lineal yard of filter; an amount so small that it would flow away in a stream an inch deep, with a velocity of little over a quarter of a mile an hour. And this leakage would represent the work done by 200-feet head of water, in forcing a passage for such a stream through the obstruction presented by the filter, and imparting to it the velocity with which it issues from the lower edge.

If this prismoidal filter be supposed to be laid on its side upon an impervious soil, and the casing containing it be removed and replaced by slopes of fine sand in front and of filling in rear, care being taken to keep open a drain of dry stone, or of masonry arches, from what was previously the lowest edge of the filter (Fig. 14), the result is a bank so

FIG. 14.



THEORETICAL BANK ON STRONG IMPERVIOUS GROUND.

constructed as to fulfill the five conditions already stated for a safe bank, but without any puddle. The higher the bank for a given coarseness of sand, and the thinner the layer of sand forming the front slope, the more water would flow through the bank; but even if the leakage increased a thousand times, and the water poured from the rear of the bank like the back lash of an Atlantic storm wave, there is no engineering difficulty in securing the rear so that the water should pass out without disturbing the outer toe of dry rubble blocks; and if these do not move, no particle in front of them can be displaced, by hypothesis, except by actual crushing of the material. It will be observed that no crack nor burrow can be made in the material of this bank, either by sun or vermin; and that it only needs its surface protecting from the action of rains and waves to form a durable bank.

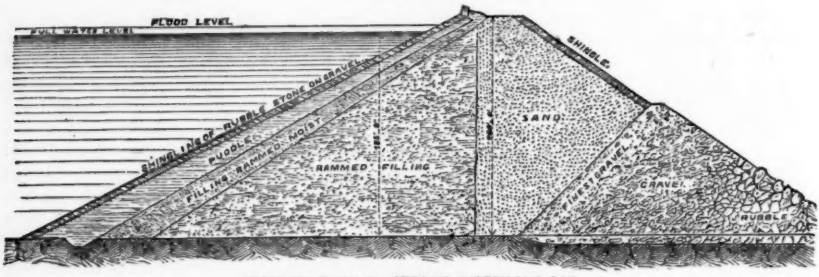
In the author's opinion, there is no other sound and safe principle on which earthen banks of tanks or reservoirs can be constructed except that described. In practice, puddle is added to stop the leakage, and the durability of the bank is thereby also increased. But a reservoir bank can hardly be considered safe if, owing to the mode of its construction, a crack, burrow, or other leak through the puddle, would be dangerous to it. In practice, the best position for the puddle is on the flattest slope in front of the bank (Fig. 10), where it should be protected by rubble, the larger and smoother the better, laid on sharp loose gravel impervious to vermin. The thickness of this protection must be so great that it cannot be wholly removed as the bank settles. Rubble packed, or very rough stone, as kunkur, is best avoided; since it will not follow the bank during settlement: hence the dry rubble facing must be thicker as the bank is higher. Unless there be liability to a scour along the inner toe, there is no occasion to make it thicker at the bottom than at the top, but rather the reverse, since the waves will be heaviest when the tank is full. The puddle will be the most dense part of the bank. Where used by the author, the surface of puddle under construction is kept always flooded, like a rice field; and gangs of men, with their arms linked together, walk backwards and forwards on short lengths of it all day, treading it stiff to a song, as layer after layer is added by the workmen. The thickness of puddle used for banks under forty feet high is just one foot thinner than that used in the bank of

the Sheffield Waterworks Company, which did so much damage by bursting on the 11th of March, 1864; *i.e.*, it is three feet thick at the water-line, and increases at the rate of one foot in thickness for every eight feet vertical depth below the water-line. The puddle must, if necessary, be carried down in a trench —sheet piling also being added if necessary—so far as to prevent any flow of water below it being so violent as to displace material, or so copious as to be wasteful.

In order to insure the puddle remaining watertight under all circumstances of original settlement, and of alternate wet and drought, it is desirable that it it should rest on a substance rather more compressible than itself. To lay it at once on ordinary rammed filling would be too violent a change; and it has always been laid by the author on a cushion of earth moistened and rammed; each layer, of six inches or so, being well wetted and then sprinkled with enough dry earth to prevent it sticking to the rammer, when punned with a rammer of forty pounds weight. The rest of the front slope, if not already existing, has been made of earth rammed dry in the usual way; since it was found safest, indeed almost necessary, to establish the broad rule, that nothing but earth should be brought to the front of the center line of the bank. The bank was then completed with any gravel or bad soil available, the gravel being kept at the bottom as much as possible, and the finest soil to the center. Though such banks are not theoretically perfect, they have never failed nor given trouble upon letting the water against them. The lengths entirely constructed on these rules are insignificant, but about five miles of old bank have been faced with puddle laid on earth rammed moist.

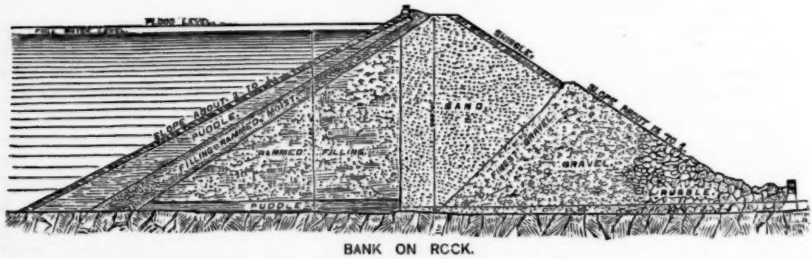
The form recommended by the author for higher banks is shown in Figs. 15, 16, and 17, which only needs a remark, that where the bank runs out on a hill-

FIG. 15.



ORDINARY BANK ON STRONG IMPERVIOUS SOIL

FIG. 16.

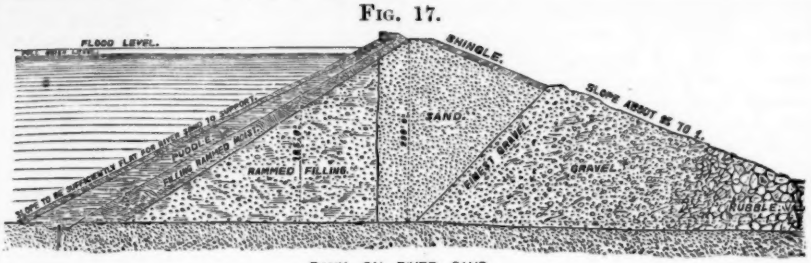


BANK ON ROCK.

side, or the ground along the center line of the bank rises or falls, the water which leaks through and under the puddle will be liable to run along inside the bank, instead of escaping out of the rear toe at once. Hence, at the deeper parts of the bank, larger stone is desirable at the outer toe, whatever other artifices the nature of the ground may admit of.

The greatest average monthly progress

FIG. 17.



BANK ON RIVER SAND.

in any year made on the Soonkesala and Cuddapah canal was 273,000 cubic yards of earthwork and 11,572 cubic yards of masonry, in the working season, April to March, 1869-1870; but this could be exceeded were labor concentrated in one spot and assisted by machinery.

The cost of earthwork varied from 2*d.* to 6*d.* per cubic yard; of rock cutting, from 6*d.* to 2*s.*; and of rubble masonry, from 5*s.* to 10*s.*, the latter including a little cut stone.

Much rubble masonry, including arch work, was done in aqueducts and bridges, as in the whole of the 9th section of the canal, at the rate of 8*s.* a cubic yard over all, with centerings found. Earthwork in black cotton soil six feet deep, or thrown into banks, was done rapidly during the year 1870, at 2½*d.* a cubic yard.

The actual cost of the first seventy-five miles of canal—the length whose main office is to carry water for distribution below—has been £8,710 per mile, including headworks. The next 115 miles, including locks and all works, has cost £2,900 per mile; and the whole canal, including the expensive weir across the Penner, has cost £5,260 per mile. These rates include all English stores and plant used for the work; but to cover the cost of engineering, management, and stores in stock never issued for use, fifty per cent. requires to be added to the above figures.

The powers of irrigation possessed by the canal, as it at present exists, admit of a clear but not very precise definition, owing to the number of contingencies for which it is adapted, but which are not yet determined by experience. If rice alone be considered, the irrigating power possessed by the canal, estimated at two cubic yards of water an hour per acre where the waste water is lost, and 1½ cubic yard where it is again taken up by the canal below, is—

In the Toombuddra Basin... .	50,000	acres.
In the Caulee Basin.....	30,000	"
In the Koondêr proper.....	100,000	"
In the Penner proper.....	3,300	"
Total.....	183,300	"

To which can be added, at an expenditure of 2*s.* an acre—

In the Caulee Basin.....	17,000	acres.
In the Koonder proper.....	50,000	"
Grand total...	250,300	"

Since the supply amply suffices for growing a second crop of wheat for every acre of rice, and it is already found that this cultivation is commencing, during the first season of the canal being opened throughout, the revenue possible at the present water rate of Rs. 6 an acre, and assuming no first crop irrigated except rice, is £300,000; and the yield, at the average yield of five years under tank irrigation in the Kurnool district, would be above 300,000 tons of rice grain, and about 500,000 tons of rice straw, and about a third of that weight of wheat and wheat straw; quantities which could be increased by the importation and use of manure. But in order to grow so much rice, the irrigation of dry crops, such as indigo, cotton, &c., would have to be neglected; though the demand for irrigating such crops is, so far, as extensive as that for rice.

In reference to navigation, the capability of the canal seems ample; and it may be necessary to explain the reasons for this. The Board of Directors were desirous of commencing with locks of a smaller size—more like the inland locks on English canals—but at the desire of the Madras Government, expressed in 1866, this was given up. Supposing the accommodation for traffic on the canal

to offer no greater attractions to the native public than that of a railway, the weekly traffic may be estimated as equal to that on the N. W. line of the Madras railway when open to Muttonpulley—or say £5 per mile a week. If to this be added the immense traffic created by the canal itself, more than equal to the whole then traffic of the N. W. part of the Madras railway, the result will be as follows:

The total population of the districts through which the canal passes is about 700,000; a population capable of consuming annually 127¾ million measures of rice if they ate nothing else. The possible yield of grain is 250 million measures of rice, and 83⅓ million measures of wheat. Supposing that 250 million measures of grain are not eaten by the local population, the only means of getting rid of them freely is by the canal, and this gives, at three pounds a measure, above 300,000 tons. If this quantity be carried annually over half the length of canal, it gives a daily traffic of 500 tons a mile every working day; to this must be added straw, manure, and the commodities purchased by the sale of the product, besides all the traffic which a railway would have, as above estimated.

But a brief comparative sketch of the Madras Irrigation and Canal Company's canal between Soonkesala and Cuddapah, and of the Grand Junction canal between Brentford on the Thames and Braunston, will give as good an impression of the work as any technical description can do.

The Grand Junction main canal is 90¼ miles long, 4½ feet deep, thirty-six feet broad at the top, and twenty-four feet broad at the bottom. The Soonkesala canal is 190 miles long, of which seventy-five miles are never less than 100 feet in average breadth, nor eight feet in depth, and average about 253 feet breadth at the top, and nine feet in depth. The locks in the English canal are eighty-six feet long by fifteen feet wide; in the Soonkesala canal 120 feet by twenty feet, or nearly twice the size. The navigable branches of the Grand Junction are twenty-eight feet, and even twenty feet broad at the water level; while the narrowest portions of the Soonkesala canal are seventy feet, or, for a few miles, sixty-five feet. The former has 102 locks, averaging 7½ feet rise; the latter has only forty-seven locks (reckoning double ones as two, and besides three level floored locks), averaging 9¾ feet rise. The former was commenced about 1795, and was completed as follows: fifteen miles were opened up to November, 1797; 28½ miles more were opened in June, 1798; 20½ in 1799; 25¾ in 1800; 6½ in October, 1800, and three more, including the Blisworth tunnel, in March, 1805; making, with the Paddington branch opened in 1801, a total of 102¼ miles completed in ten years, at a cost which ultimately reached about £2,000,000. The Soonkesala canal, 190 miles long, was commenced in October, 1861, and was all brought to completion, as required by the Company's engagement with the Government, in June, 1871, or in about ten years, at a cost which, when it includes wharves and floating stock, will reach about £1,750,000. It would probably have been better had the Grand Junction canal been originally constructed of the size of the Soonkesala canal; for, though it worked profitably to itself—so much so that its £100 shares rose to above £200—yet it proved too small to accommodate the traffic it developed, and has therefore sunk for the present under the competition of the railways. It is interesting to compare the size of the towns affected by the two canals at the time of their opening. London had then 864,845 inhabitants; Madras has about 760,000. Northampton had 7,020; Derby, 10,832; Dudley, 10,107; Walsall, 10,400; and Birmingham, 73,670. Kurnool has about 12,000; Cuddapah, 25,000; Nundial, probably 7,000 or 8,000. Again, the producing and manufacturing powers of the two districts are strikingly similar, though in contrast. The Grand Junction canal promoted the production of coal, iron, and lime from below the earth's surface, and the industrious manufacture of exotics by machinery; the Soonkesala canal cannot but promote the production of material for food, clothing, and luxury upon the earth's surface, and the manufacture of food, cloths, colors, paper, &c., for which the Madras Presidency was formerly celebrated over the whole of Europe and Asia; and for this work the population is likely soon to be adequate.

REFRACTORY MATERIALS.*

By T. EGLESTON, Ph. D.

From "The Engineering and Mining Journal."

Although the success of metallurgical operations depends so largely on the possibility of finding proper refractory materials, and they enter so prominently into the cost of their operations, it can hardly be said that our knowledge of them is in a very satisfactory condition, or even that we know very much about them, beyond a few facts which have been gathered through their use. Experience, as a general thing, is an excellent master, but the requirements of modern metallurgy increase so rapidly that the acquirements of experience become rapidly useless, because the exactions of temperature are so rapidly increased, that the material depended on yesterday is of little value to-day. No material is required to resist so many and so varied conditions as crucibles, retorts, and furnace-linings.

In the use of a given refractory material it will often be found that the same substance is called upon to fulfil conditions, which are not only different, but exactly the reverse the one of the other. At one time it must resist an oxydizing, and immediately after withstand more or less of a reducing action. Now the action must be neutral, followed by the corrosive action of scorias, or sulphuric acid, or it must withstand the action of basic scoria, and immediately afterward only resist the action of metals in fusion. The same substance must resist the destructive action of melting as well as melted oxides, sulphides, and silicates, and at the same time be proof against any amount of heat. We seem to be astonished, and often complain, that one brick which resists the influence of oxide of iron, should fail entirely under a gas flame, and that one should slag under the influence of oxide of iron, but resist any amount of clear heat, and yet, when the nature of the material is considered, we see that it could not very well be otherwise. In many cases, and in certain portions of a furnace, the brick may be called upon only to support a very high temperature, coming in contact with the flame only, and this is the most trying condition of all our modern requirements, for under these conditions the material must resist the temperature, and remain infusible without decomposition, cracking, or alteration of any kind, and still retain strength sufficient to resist the pressure of the furnace.

The conditions which the refractory materials of to-day are called upon to fulfil, are very different from those demanded a few years ago, and unless a better, and, at the same time, a cheaper material than we have now, can be found, there are some industries which must die out altogether, and others, which, if they survive at all, can never take the commercial place which their metallurgical value would otherwise command for them. Mr. Holley has shown that the cost of the refractory materials of the Bessemer process, is one dollar per ton of ingots, that in this country for the Siemens-Martin process it is five dollars per ton of ingots, while in Wales it is only one; a difference in cost, other things being equal, sufficient to almost prevent competition in times like these. We must fairly regard the condition of our knowledge of this subject as one of the weakest sides of modern metallurgy. A review of it at this time, when we are called upon to economize in every direction, may not be out of place, for there are few departments about which there is so much scope for economy as here.

The substances with which we have to deal as refractory materials are silica, alumina, lime, magnesia; clays, which are silicates of alumina, more or less pure; the hydrated aluminate of iron, known as bauxite, and some silicates of magnesia, as talc, steatite, and the minerals which are allied to them, all of which substances are fusible in the strict sense of the word, but are generally infusible at commercial temperatures. To these substances two others must be added as powerful agents to render in-

* A paper read before the American Institute of Mining Engineers, at the Washington Meeting, February, 1876.

fusible, under certain conditions, substances which would otherwise be fusible, and these are water and carbon, in the shape of coke or graphite.

Some few rocks are used as refractory materials, without undergoing change. These rocks are quartzites, granites, some sandstones, conglomerates, serpentines, steatites, and, in certain rare cases, as in Styria, carbonate of lime. Quartzite and sandstones were, for a long time, used almost exclusively for blast furnace hearths. They are very refractory, but very treacherous, as they are not homogeneous. Some aluminous shales are also used, and will, generally, resist, if they do not contain more than from four to six per cent. of iron, the alkalies and the alkaline earths together, but it is not easy to use them. They are not easily cut, must be laid in their quarry-bed, and are liable to crack. Other rocks, of the soapstones and serpentine varieties, which contain sixty to sixty-five per cent. silica, and twenty to twenty-five per cent. magnesia, are infusible, easily cut, and, if they do not crack, can be used; but, in general, natural substances are not homogeneous, are difficult to get in sufficient quantities, and so little to be depended upon that artificial materials are preferred.

Silica is found in nature as anhydrous and hydrous. The anhydrous, which is quartz and jasper, cannot be used alone, as it cracks and splinters. If it is to be used, therefore, it must be reduced to powder. The hydrous varieties gelatinize with acids, and are found as powders and soft stones, which pass under different names in different countries. They contain from thirty to eighty-seven per cent. gelatinizing silica, from two to ten per cent. water, and from 0 to 40 per cent. insoluble silica, with from two to ten per cent. of iron, alkalies and alkaline earths. These impurities are generally in too small quantities to affect its refractory qualities. The rock is so tender, that M. Deville has had crucibles made in a lathe out of it; but, as the composition is never regular, vessels made by mixture are always better. Though silica is infusible, it cannot, generally, be used without being ground, and as it has no binding property like alumina, a small portion of binding material must be added to it to make it hold together. For the Dinas brick, which is the best substance to resist heat alone, this binding material is lime. The brick is made of quartzose sandstone, which is first heated in a furnace, and thrown into water, to break it up, and is then ground. It is composed of—

SiO_2	98.31	to	96.78
Al_2O_3	.72	to	1.39
Fe_2O_3	18	to	.48
CaO	22	to	.14
Na,KO	14	to	.20
HO	35	to	.50

The amount of lime required to bind it together is 1½ per cent. The joints between the bricks are filled with the same material. At a temperature of 2,200° C., about 4,280° Fahr., these bricks will last four weeks in the roof of an ordinary furnace, and in that time will be reduced—by abrasion of the flame, and dust, and slightly from chipping—from nine to two inches. The bricks conduct the heat so badly, that at this temperature, which is a bright white heat on the inside of the furnace, it is only just warm on the outside. Ordinarily, the bricks seem to be fluxed away by the dust, which circulates with the gases. In the Siemens furnace, where there is no dust, they give out from weakness. They cannot be applied to any part of the furnace where there is any wear. Their principal cause of deterioration seems to be, the lowering of temperature due to stoppages on Sunday, when the bricks flake, either as the furnace cools, or when it is again heated. It was at first supposed that these bricks could only be made from the Dinas stone, but it is now known that they may be made from any pure silicious rock which has been ground and mixed with the proper quantity of lime.

In ganisters, used for the Bessemer converters, the binding material is alumina, chemically combined with silica, in the shape of clay. It is generally used unburned, and it is very important that the mixture should be so made, that it will expand a little, but not shrink at all. For this purpose, quartz, as pure as it can be had, is mixed with aluminous clay.

Silica is generally a very cheap material, and preferable to any other substance, if it is used only to resist heat, but cannot be used if any considerable

quantity of scoria are formed. In such cases bauxite, or other aluminous material, will be found to be preferable.

Lime, or lime rocks, cannot generally be used in commercial operations, because the carbonate, the only form in which we have it, becomes caustic under heat, and this, when left to itself, absorbs water and falls to powder. It can be used when an operation is continuous, but in no other case. In Styria the hearths and sides of blast furnaces are sometimes made of it, but they are generally quickly abraded, and make but short campaigns. Lime is infusible; bricks of it are used for the fusion of platinum. It is, however, very easily acted upon by silica, but when this is absent, it is one of the most refractory substances known.

Magnesia, made from the carbonite by driving off the carbonic acid, is very refractory, if pure. It is made into any shape that is required, and is one of the most refractory of substances. It was formerly very difficult to get the carbonate of magnesia, but large quantities of it have been found on the Island of Eubea, so that it can now be had for $15 to $25 the ton, instead of $60 to $70 as formerly. It can be calcined at a less cost than ordinary lime, losing half of its weight, so that if calcined before it is transported the cost may be still further reduced. It contains a little lime, silicates of iron, and some serpentine and silica. After calcination, the serpentine and silica can be separated, as it is easily crushed, but the most of the work can be done by hand picking beforehand. Before moulding, it must be submitted to about the temperature it is to undergo in the furnace, otherwise it would contract. It is then mixed with a certain portion of less calcined material, which is one-sixth for steel fusion, and ten to fifteen per cent. water by weight, and pressed in iron moulds. If for any reason—either because there was too much or too little water, or because the material was not properly mixed, or contains silica—the crucible is not strong enough, it has only to be dipped in water, which has been saturated with boracic acid, and then heated.

Bauxite is one of the natural substances which has been recently applied as a refractory material. It is a compound of silica, alumina, and water. Like all aluminous substances, it has the advantage of tending to form aluminates which are less fusible than silicates, and are generally completely infusible at commercial temperatures. It does not have a very constant composition, as silica is sometimes not even present at all. As is shown by Berthier's analysis given below:

	Berthier.	Deville.	School of Mines.
Al_2O_3	52.0	58.1	60.00
Fe_2O_3	27.6	3.0	0.80
SiO_2	....	21.7	23.00
HO	20.4	14.0	15.00
TiO_2	....	3.2	.....
	100.0	100.0	98.80

Almost all the aluminates of iron are infusible. Siemens has taken advantage of this, to make bauxite bricks, which have the composition: alumina fifty per cent.; sesquioxide of iron, thirty-five per cent.; silica, three to five per cent. They last five or six times as long as the best Stourbridge bricks. Nothing has yet been found which resists the corrosive action of basic slags so well.

The materials of which fire bricks are generally made, however, are fire clays, which are hydrated silicates of alumina, containing from fifty to sixty-five per cent of silica, thirty to seventy-five per cent. of alumina, and eleven to fifteen per cent. of water. The relation between the silica and alumina is exceeedingly variable, owing to the fact that a part of the silica, which is not always the same, is combined and a part uncombined. The quantity of water is also variable, as part of it is hydroscopic and can be drawn off without injury to the clay. The plasticity generally depends on the water of combination, which, when driven off at a red heat, cannot be made to combine again, so that this property is then entirely lost. It contains, beside, a small quantity of other elements, such as potash, soda, lime, magnesia, and iron, and is generally less refractory, as it contains more of them. When it contains from six to ten per cent. it will generally melt. When the clay is silicious, three to four per cent. of other substances make it fusible. When it is aluminous, six to seven per cent. of oxide of iron does not make it lose its refractory qualities, owing to the very refrac-

tory nature of most aluminates. When, therefore, the corrosive effects of basic slags are to be feared, aluminous clays must be used.

Almost all clays contain organic matter; if it is present alone it makes the clay more refractory, since the presence of even a small amount of carbon tends to increase its resistance to heat, as seen in graphite crucibles. Pure material, composed exclusively of silica and alumina, would be completely infusible. Such material is, however, exceedingly rare. The property of infusibility is always more or less compromised, by the presence of foreign substances, which tend to damage it or take it away altogether. The clay, which according to Brognaird is the most refractory when deprived of its hygrometric water, has the composition: silica, 57.42; alumina, 42.58.

While the refractory nature of clay is due, to a very great extent, to its chemical composition, it is not due to it alone. There are, probably, no two beds of clay in the world, or distant parts of the same bed, that have exactly the same composition, and yet they may be very nearly of the same quality. The power to resist heat is, undoubtedly, owing in part to the molecular condition of the particles, a subject which has been but little studied, and is but little understood. Many clays, which would be rejected from chemical analysis alone, are sometimes found in practice to be excellent refractory materials. It has been found that the refractory nature of the clay depends also to a great extent on the mechanical arrangement of the particles, for of two materials having exactly the same chemical composition, one being coarse, and the other in a fine powder, the coarse may be practically infusible, while the fine may be more or less easily fusible. The more porous the same substance is, the more infusible it will be. It may be said in general terms that the value of a given refractory clay will be inversely as its coarseness and as the amount of iron contained. When the amount of iron reaches five per cent., the material becomes worthless. This is true, however, only in general, for Pettigand cites an excellent clay from Spain, in which there is twenty-five per cent. of iron. This is, however, an exception, and will be referred to again.

In order to be useful, clays should be, or should be made to be, more or less plastic, as this property is necessary to their being moulded into the shapes required. This plasticity is owing—first, to the fineness of the particles, to the presence of alumina, and to the water of combination. It is diminished by the presence of iron, lime, and magnesia. The refractory nature of the clays, then, is due to the presence of alumina, and to the absence of potash, soda, lime, magnesia and iron. The characteristics of all fine clays may be said to be that they do not effervesce with acids, that they make a paste with water, which is absorbed so rapidly as to make a slight noise. This paste can be drawn out without breaking, and is very plastic. Dry, they are solid, and break into scales when struck. They have a soapy feel, are scratched or polished by the nail; can be cut into long ribbons with a knife, and appear somewhat like horn. When fresh from the quarry they have a more or less fetid odor, owing to the presence of some decomposed organic substances. In composition they contain, as we have seen, either silica or alumina in excess. Silica in excess makes them rough, and takes away most of their plasticity and tenacity. Alumina makes them very plastic; magnesia makes them very unctuous, and almost soapy, but does not make them fusible; lime makes them dry and fusible; iron and other substances change the color, and, beyond certain very restricted limits makes them fusible. The gray and brown colors, up to black, are owing to a small percentage of bituminous material. White clays are generally considered the best, but there is no certainty about it, as they often crack, or even melt. It is generally an excellent sign when they leave unbroken lines when scratched by the nail. It is, however, never safe to judge by the eye or touch, as some of their chief characteristics apply equally well to materials not in the least refractory, and even those that are peculiar to them may be taken away by improperly drying them, by carelessness in storing or handling them, or by allowing them to become mixed with other substances. A preliminary analysis gives only a general

idea of their nature, but it is not always a safe guide to the manufacturer, who needs first an analysis and then an assay, for some of the most inferior clays, if we should judge by their analysis, give excellent results when used as mixtures. Analysis is necessary both before and after the assay, but there is a molecular force which seems to have more to do with the value of the material than the chemical composition. The greater this force is, the less likely the heat is to overcome it, either to cause disintegration or chemical union. If possible to do so, all clays should undergo some process of preparation, with a view of purifying them.

Every person using clays should endeavor to get a certain knowledge of their properties by assay. There have been a number of these assays published. The two simplest and best are, the one proposed by Bischoff, and the foil assay.

Bischoff's assay is based on the comparison of every clay with one from Garnkirk, in Scotland, which is taken as a type. For this purpose, the clay to be examined is mixed with one, two, three to ten parts of quartz. It is then raised to a known temperature and compared. If the clay, with three parts silica, acts like the Scotch clay with one, it is called three, and so on. The best and simplest assay seems to be one made by the blowpipe, which consists in mixing a small quantity of clay with water, and then spreading it out carefully on a piece of platinum foil in a very thin sheet, which when completely dried is submitted to the flame and compared with clay of known fusibility prepared in the same way. Very few clays can be used as found. They must be, as it were, suspended in some infusible material, which will prevent, as far as possible, the mechanical effects of the heat, and allow, at the same time, of a certain amount of expansion and contraction, while preventing both in too great a degree. These materials are generally called "lean," that is, they do not make a paste with water and require some binding material to keep them together. They are usually quartz sand or pulverized quartz, burnt clay, old bricks, serpentines, talc, graphite in powder, and not infrequently small coke, when the ash is not to be feared, and when graphite either cannot be had, or cannot be used on account of its high price. Some few clays from Spain contain this material, which comes from the decomposition of talc shale in which they have been suspended by nature, but this is a rare exception. The mixture must generally be made artificially. Of all these substances quartz sand is the cheapest, but it has been found by experience that round grains of sand are less liable to become thoroughly incorporated with the binding material than the angular pieces of crushed quartz, so that when a very refractory material is required crushed quartz is always used. As the clay contracts, and quartz expands, a mixture may be made which will not change its form; but in a given case this may not be the best mixture for a special use. If the material has only to resist great heat, an excess of quartz is preferable; but if it must also resist the corrosive action of basic slags, clays burnt at a high heat, graphite or coke can be used. When the mixture is made in the place where it is to be used, without previous burning, it is generally made of one-fifth plastic clay and four-fifths burned clay or quartz, or one-fourth lean clay and three-fourths burnt clay or quartz. This is done to avoid contraction. It is a most economical construction, even in blast furnaces, and is coming more and more into use.

The clay, when mined, is left exposed to the air under sheds, and is cleaned and carefully dried, and is afterwards mixed with the substances with which it is to be incorporated, which are classified by numbers, varying according to the size of the sieve holes through which they will pass. The quantity and quality of the mixture will determine the refractory nature of the material to be produced. A friable paste with large grains, and quite porous, resists a great heat. One with fine grains, close and compact, splits at a high heat, especially if it is not homogeneous. The manner in which the mixture is made also influences the quality of the brick quite as much as the material. In some works in Belgium, after taking all the ordinary precautions to make the mixture perfect, it is submitted to a succession of shocks continued for some time, until it is found by experiment that the materials are per-

fectly mixed. It has been found by long experience that the bricks so made kept their form perfectly, while others made of exactly the same mixture in the ordinary way contract. The quantity and size of the mixture depend upon the size of the article to be manufactured. When coarse grains are used, greater thickness must be given to the sides of the articles if they are hollow, and they must be made larger if they are solid, thus giving a mechanical cohesion where a chemical one is wanting. The usual quantities of the mixture are two-fifths to two-thirds of the substances added to two-fifths to one-third of the clay, these quantities being determined by volume and not by weight. When coke dust is used it does not seem to have any decided effect beyond one-tenth. The action of coke or graphite is to decompose the metallic oxides as they form, and thus prevent their union with the material of the crucible. Coke may be profitably used in the place of graphite when the ash is in small quantity, free from iron and highly aluminous. Beyond two to three per cent. graphite cannot be profitably used, as it weakens the article and renders it liable to break. The mixture which gives the very best results for small objects is, however, worthless for large. It will generally be found that the pieces which crack up and down in drying have had too much material mixed with the clay, and those which crack laterally have had too much clay.

The very greatest importance is attached in some industries to not having a mixture made by a machine. In most places even to this day the inhuman method of heel treading is used, because either from the fact that more care is exercised, or because smaller quantities are mixed at once better results are obtained. The more the operations of mixing are repeated, the better the material, and it is undoubtedly true that with mechanical means such a homogeneous paste is not produced as can be made by human labor, because the whole object of the machine is to operate on large quantities at a time.

The paste made, and the article completed, it must be dried or "tempered." This is commenced in the open air, and if possible out of the draft. If the draft cannot be excluded, the place where the drying takes place is slightly heated, commencing at a temperature from 60° to 70° Fahr., and keeping it up from twenty-five to thirty days, then increasing it from 80° to 100°, leaving the article as long as possible, and so on, an active ventilation, but the same temperature, being kept up. The article should remain in a temperature of from 150° to 180° for at least six weeks. Bricks do not generally require so much care; but crucibles and retorts do. Long experience has proved that there is a great economy in conducting this process of tempering as slowly as possible, and that it influences materially the refractory nature of the article. It is found by actual experiment in crucible works, that those crucibles made from the same mixture, tempered during six to eight months, last more than three times as long as those which had been tempered only two; so that in general the older the article before being burned the better. This desiccation, while perhaps it is the most important part of this manufacture, is undoubtedly the one most neglected. A poor article well tempered is often better than the best which has been hastily dried. By working rapidly, and filling up cracks as they form in a too rapidly heated drying house, with a very liquid material, in order to secure complete penetration, both time and money are lost. The material never lasts nearly so long as when slowly dried. In the works at Andenne, in Belgium, large pieces, like glass house pots, are kept six months in the drying house before they are burned, and during this time the greatest care is taken to prevent drafts, and in allowing any air colder than the drying room to strike them. Leaving the door of the drying furnace open has been known to crack the pieces, which had been up to this point most carefully prepared and tempered.

In reviewing the effects which the different elements which constitute refractory materials have, we find that the same element often produces exactly contrary effects, according to the proportion in which it is present, and that there is nothing anomalous in those effects being so produced. Silica causes expansion when highly heated, so that

the moulds in which the bricks are made must be smaller than the brick is to be. Every mixture has its own peculiar rate of expansion and contraction. This expansion not only takes place when the bricks are made, but if when used they are submitted to a higher degree of heat, they expand still further, and contract again on cooling to such an extent, that at Dowlais the tie rods of the steel furnace are slackened when the furnace is getting into heat, and are tightened again as it cools. At Crewe, this is made self-acting by means of springs. At Creusot the furnace casing is made so strong as to resist the pressure, so that the center of the roof arch must rise and fall, to allow for the expansion and contraction. When neutral brick must be had for any reason, it is mixed with just enough clay and burned brick to make it keep its form, and such a brick is generally less fusible, as it contains less silica.

Alumina alone, or with silica in the proportion of thirty to thirty-eight per cent., is very refractory; but three per cent. of it in a silica brick makes it fusible. In clay, or pure, it tends to contract, and this tendency is greater as the alumina is in greater quantity, and the heat of manufacture has been low, but when it has been very highly heated at first it afterwards undergoes but little change. Though both silica and alumina affect each other so unfavorably, Bischoff found that four of alumina to one of silica or two to one, or one to one, only sintered before the oxyhydrogen blowpipe, making masses with a granular fracture. One of alumina to two of silica was fusible like porcelain, but still somewhat granular. One of alumina to four of silica, and one or alumina to six of silica melted like a thick enamel, which shows that the acid silicates of alumina are much more fusible than the basic. He also found, that a mechanical mixture of alumina and silica was less fusible than the same amount in a natural combination, and that in general silicates already formed are more fusible than a mixture of their constituents. The general property of alumina, when mixed with other substances, is to bind them together. When combined with iron or other bases alone it makes infusible aluminates; but if silica is present, it fuses more or less easily. It is generally conceded that the proportion of alumina in a brick should be between ten, twenty and seventy-five per cent.

The alkalies in small quantity make a brick fusible. There is a great difference of opinion among those who have studied this subject with regard to the quantity. Mr. Snelus states positively that one per cent. of alkalies in an otherwise good material makes it too fusible to withstand high temperatures. Mr. Riley states, with equal positiveness, that he has found brick containing 2.73 per cent. of potash to resist the greatest heat of a Siemens-Martin furnace. It is probable that both are right, and that in the special cases alluded to, the peculiarities were owing to the association of elements. In any case, a material with a very small percentage of alkalies cannot be used.

Lime alone is completely infusible; but in very small quantities in a clay, it makes a brick fusible at high temperatures. One per cent. of it with silica makes the most infusible brick known. Magnesia in small quantities makes the clay fusible. In very large quantities it is very refractory. Alone, it is entirely infusible.

Oxide of iron in the absence of alkalies, may be present in small quantities without seriously affecting a clay, unless it is to be used for melting steel. If alkalies are present, any proportion of iron would make such a clay worthless. If no silica at all is present, five or six per cent. may not damage it. In a silica brick two to three per cent. of iron makes the brick worthless. If the iron was always certain to remain in the state of a sesquioxide, its compounds would be much more infusible, and a large percentage would do no injury; but some of the sesquioxide is certain to become reduced to protoxide in the presence of reducing gases, and the result is a very fusible compound in the presence of silica.

There is a still more deleterious and dangerous effect of iron in fire-brick, because its effects are produced, not at a high heat, but at a comparatively low temperature. It is well known, since the researches of Bell and others, that when a brick, containing iron, is exposed even at a low temperature to gases containing carbon, that part of this car-

bon is deposited near the iron; this has often not only caused the brick to lose its cohesion, but may even burst it, so as to throw down the iron walls of furnaces, and the linings of flues. The presence of iron is, therefore, doubly to be dreaded, as its presence is quite as deleterious at low temperatures as at high.

As much as one per cent. of titanium has been found in some clays. Little is known about it; but it appears to act like silica.

Bischoff found that twenty per cent. of magnesia, twenty-eight of lime, 47.1 of potash, or forty per cent. of iron, had exactly the same effect in making the clays fusible, and that when four and two of the different bases were used, the relation was striking, and in about the same order. The quantity of other substances necessary to make a compound fusible, depends upon the quantity of silica present—the more the silica the less the quantity. It will thus be seen that while the predominance of any one element will materially affect the nature of the materials, it is more the way in which the different ingredients are grouped together than their individual percentage, which affects the nafure of the brick, and frequently, above all these, the mechanical and molecular arrangement of the particles which determines its commercial value.

The essential qualities of a good brick may be stated as follows: first, uniformity: second, regularity of shape, and the power to retain it under all circumstances, which involves perfect unity of composition; third, strength to resist the different pressures required under different circumstances; and, fourth, its cheap price. No material yet manufactured fulfills all these conditions; but there seems to be no reason why, with the proper investigation, a material should not be made which will fulfill most of them. The metallurgical world is nearly agreed that the refractory material of the future must be made artificially, and that it is hopeless to look for it among natural products. No brick can come up to the modern standard of infusibility, which contains five per cent. of iron, or three per cent. of combined alkalies or alkaline earths, yet the most infusible brick that is known, which, in the roof of a Siemens-Martin furnace will resist during 250 charges, and then wear out by abrasion, when required to come in contact with metals, oxides, and alkalies in a spiegel cupola, will hardly stand twenty-five heats, while an iron pipe coil, which is easily destroyed by heat, will last almost indefinitely in the same cupola, provided only a sufficient stream of water is run through it. Different furnaces, and different parts of the same furnace should, therefore, be treated differently, instead of being treated by the same Procrustean methods, as is frequently the case. If silica makes the best roof, it makes the worst hearth. Alumina, when present in very large quantities, even in the presence of a small amount of silica, makes compounds which are almost infusible, so that it should be used for the fire bridges and hearths, and not put into the roof, where its tendency to contract would endanger the structure of the furnace.

Far too little attention has been given to the abrasive and corrosive power of coal dust and ashes carried by the draft, in gradually cutting and fluxing away the parts of the furnace exposed to its action, and many qualities of brick which are infusible in the assay, owe their small power of resistance to its effect. A brick to be used where is to be exposed to such action, should always be tested by placing it for a considerable time on the bridge of the furnace where it is to be used, for the destructive effects of this almost unobserved agency seems to be greater than those of long continued heat.

A good brick should not only resist high temperatures, but sudden changes of temperature, without alteration of any kind, such as crushing, splitting, etc., and at a high temperature should undergo the least possible change of form. In general, it may be said, that bricks which have undergone a very high temperature in the manufacture are less likely to contract afterwards. Shrinkage is generally due to insufficient burning, or to a too small proportion of old material in the mixture, and generally occurs in aluminous bricks. Its chief evil is in allowing the flame to penetrate the open joints and give the dust an opportunity to cut between the bricks, for any cause which produces eddies in the flames, such as

hollows or projecting surfaces, is certain to effect the destruction of that part of the furnace. Silicious bricks have, on the contrary, a tendency to expand under the influence of intense heat. This is true to such an extent that in the steel furnace where they are used provision must be made for slackening the tie rods when the fire is being raised, and tightening them when it is being cooled.

The crushing weight of an ordinary fire-brick, cold, is from 600 to 1,000 pounds, but some of the best have been known to resist as high as 3,000 pounds to the square inch. To insure the safety of the structure and the success of the process, it should not only retain its power of resistance, but should not undergo any change of form nor soften materially under long continued heat, and at the highest possible temperature should support more than double the strain required without attention. In the walls of the fire-place those bricks will be best which are dense, and contain an excess of silica. In the hearth they should contain an excess of alumina. In the arch they should be nearly pure silica, alumina, or magnesia. Bricks in a roof give out from shrinkage, cracking, or splintering. Splintering takes place when silicate bricks are made of impure mixtures, usually from too much fine material and from imperfect burning. Bricks which are liable to splinter are generally cross grained and dense, with a smooth conchoidal fracture when made from improper mixtures, and when from bad burning they generally ring like a cracked vessel. All good bricks wear off evenly.

No matter how good a material may be, if its price is so high as to prevent healthful competition, it might as well not exist. Hence any effort to furnish a good material should have for its aim to produce it at the least possible cost.

In discussing a refractory material in a given locality, there is to be taken into account—first, the clay and other materials to be had; second, the ore or metal to be treated; third, the fuel to be used; and fourth, the foreign substances in the gangue of the ore or metal. Whether to use one clay, or a mixture of calcined or raw clay, must be determined by direct experiment, and then the size of the grains of the mixture for the given use, must be determined, for each substance is more or less refractory, according as it is coarse or fine. Thus in Belgium, a porous material with a large grain is used for blast furnace brick, but a fine material with a close grain for coke furnaces, the chemical composition being the same in both cases. It must then be ascertained whether the mixture contracts or expands, for there are clays that contract and expand between one-thirty-second and one-eighth. The way in which the material tempers must then be carefully studied. It is not sufficient to have a good material, for almost as much depends on its manipulation as on the material itself. To temper properly, the clay and the manufactured article should both be dried gradually and uniformly. It must be fired evenly, and the temperature slowly raised to the proper point. If it is to be used in the run state as ganisters, it must be equally moist throughout, so as to dry uniformly, and not so wet as to cause it to crack in drying, or so dry as to prevent its binding. The brick, or other material, once made, should be kept from dampness, as it is porous, and likely to absorb moisture; they should be heated before being used in the furnace, and put in as hot as it is possible to handle them. If the furnace is in blast, this requires a special furnace, and a high heat. If it is to be put in blast at once, especially with silica bricks, the temperature should be as high as the hand can bear. If the furnace is to be a long time standing, this precaution is not necessary, but in the last two cases the furnace must be dried very carefully and slowly. No brick which has been dressed should ever have the dressed face exposed to the flame. Without the observation of these precautions, a really good brick may have a very bad result. It is too much the habit of this age to be in a hurry to get results, and this has led some blast furnace managers to boast, that steam was issuing from the top of their furnace, while cast iron was being tapped from the bottom; but under such management we never hear of long campaigns; but very frequently hear of disasters.

It is thus seen that a brick which is good for the cupola would be worthless for the reverberatory furnace; that which

answers well for iron, would generally be worthless for zinc, and a crucible which is excellent for steel cannot be used for brass. It is the way to realize progress to keep analyzing natural substances until we find the right one, or make repeated trials and depend upon them alone. All investigations go to show that we should look for artificial, and not for natural compounds; and that when we have made a mixture which has stood well, we are then to analyze and examine it in order to reproduce it. Failure in this, as in many other cases, is very often owing to wrong application of good materials, rather than fault in the materials themselves.

It is evident that no real progress can ever be made by any haphazard investigation. Chemical examination is, to a certain extent, a guide; but taken alone, it does not lead to any certain conclusion, for materials which on mere chemical analysis have been theoretically declared worthless, have, in actual practice, on account of some physical peculiarity which escaped observation, been shown to be of great value. Besides, a substance of no value alone may, in a mixture, be an almost indispensable article. To the analysis must be added the assay, and when these have both been carefully made, the commercial trial. After this has been done, there should be a complete chemical, microscopical, and physical examination of the substance, to determine what physical or mechanical changes have taken place, or whether it has, or has not, undergone deterioration. Only the general outline of such an investigation could be traced beforehand, and probably no one company would be justified in bearing the whole expense of it, but there is no doubt that if wisely planned and carried out, it would save millions of dollars every year to the iron and steel industries alone.

MEDIÆVAL AND MODERN CRAFTS AND CRAFTSMEN.

From "The Builder."

TRADE marks by many have been considered quite modern adoptions by makers and manufacturers, but identification of work by certain open or occult symbols is as old as history itself. The early Masonic craft had their own peculiar marks, and several of the trade guilds of the Middle Ages enforced a certain distinguishing mark being cut, stamped, or engraved by workmen of their crafts on the work they executed or offered for sale. Many instances occur in the civic records of London. In one relative to the "*turnours*," or turners, 21 Edward III, 1347, we have certain makers of wooden measures for wine, ale, &c., coming before the mayor and aldermen to account for "manifold falsities and deceits." On this occasion it was enacted, after some injunctions were given to the makers of these measures, that "in future not to make any such kind of measure of any other wood than dried, and that the measure when so made by them must agree with the standard of the alderman in whose ward each measure shall be used, and by the same standard be examined; and that each of these makers should have a mark of his own, and should place such mark upon his measure, or the bottom thereof without, when by the standard they should have been examined; that so, when any measure made by one of the makers aforesaid shall in any tavern or brew-house be found to be false or defective, these, as well as the person by whom such measure shall have been made, or he who shall have sold by such measure, shall incur the punishment at the discretion of the mayor and aldermen for the same." This was a wholesome enactment, and it would be well in these days if the manufacturer and user of light weights and measures, and the importer, wholesale merchant, and retail dealer of adulterated foods and drinks were severally held amenable. Among the old Mediæval crafts are found also more than one instance of an

enactment prohibiting one maker from using the marks of another on pain of certain penalties. In the articles of the "Heaumers" (makers of helmets), in the same year as that of the preceding trade enactments, we have it laid down "That each one of the makers aforesaid shall have his own sign and mark, and that no one of them shall counterfeit the sign or mark of another, on pain of losing his freedom until he shall have bought the same back again, and made satisfaction to him whose sign he shall have so counterfeited; and, further, he shall pay the Chamber 40s." This was something tantamount to damages in our courts of to-day for infringing certain patents. There was no patent-office in 1347, but there was protection for trade-marks notwithstanding. How slow, after all, have we moved in this country in the registration of trade-marks! It appears by the articles of the "Heaumers" that there was scamping in their trade as well as others, for it is stated before the mayor and aldermen, in the articles of the said trade as accepted at the suit and request of the men of the trade, that,—"Forasmuch as heretofore some persons coming in who are strangers, have intermeddled, and still do intermeddle, in the making of helmetry, whereas they do not know their trade, by reason whereof many great men and others of the realm have been slain through their fault, to the great scandal of the said trade; it is ordained that no person shall from henceforth intermeddle or work at helmetry, if he be not proved to be a good, proper, and sufficient workman, by the wardens of the said trade, on pain of forfeiture to the use of the Chamber."

These were the days of bows and arrows, pikes, lances, swords, and skull-crushers, when helmets for the head needed to be strong, and armor for the body almost impenetrable. Doubtless, the "scamps" of the trade made helmets that were easily pierced or battered in, and hence the great men of the realm and others spoken of were often slain. Some good regulations are included in the articles of the "Heaumers" similar to those already given in other trades. In the articles of the hatters in the same reign (1347) there are also several commendable regulations enacted for the good of the trade. We learn that bad hats were made, and mostly through allowing work to be done in the trade by night, and it was ordained that no one in future should do work "but only in the clear daylight." Wardens were appointed to make searches after hats that were "defective and not befitting, and in deceit of the common people." We learn from the "articles" of the trade that "divers manners of hats," by foreign folks of divers counties (outside London) were brought into the city and hawked about the streets in these early times, and by the articles of the trade strange persons (those who were not resident freemen or free of the trade) bringing hats into the city for sale were forbidden to sell them by retail and only by the gross, and then only to freemen of the city, on the pain of losing the same. The other rules and regulations of the trade were similar to some already described. In the ordinances of the Pewterers, 22 Edward III, 1348, there are certain special points set out respecting good work and materials, and from the requirements and acquirements needed it may be seen that the pewterers went in for a degree of technical education as absolutely indispensable to the proper practice of their handicraft. The ordinances of the trade start in the first place in this manner:—"Seeing that the trade of pewtering is founded upon certain matters and metals, such as copper, tin, and lead, in due proportions of which three metals they make vessels, that is to say pots, salt-cellars, esquelles [deep plates, or porringers], platters, and other things by good folks bespoken, which works demand certain mixtures and certain alloys, according to the manner of the vessel so bespoken, the which things cannot be made without good knowledge of a pewterer, well taught and well informed in the trade; seeing that many persons not knowing the right alloys, nor yet the mixtures or the right rules of the trade, do work and make vessels and other things not in due manner, to the damage of the people and to the scandal of the trade: the good folks of the trade do pray therefore that it may be ordained that three or four of the most lawful and most skillful in the trade may be chosen to oversee the alloys and the workman-

ship aforesaid, and that, by their examination and assay, amendment may speedily be made where default has been committed." Certain vessels of pewter and tin are described, and the proportion of alloy to be used in their manufacture. It may be interesting to state now that in 1348 the proportions of the alloy were to 1 cwt. of tin 22 lb. of lead, and articles so made were called "vessels of pewter."

The ordinances of the pewterers were very strict. Every one was to be accountable for his workmanship in the trade, and that it was of the proper materials. Journeymen or apprentices injuring their masters, or privily in the way of larceny, were punished for the first and second offences; and, if offending the third time, were ousted from the trade. No one was to be "so daring" as to work by night at the trade upon articles of pewter, "seeing that they have regard among themselves to the fact that the sight is not so profitable by night, or so certain as by day—to the profit, that is, of the community."

The ordinances of the pewterers, like some other trades mentioned, forbid the enticing away of workmen from one master for another. Journeymen, serving-men, and apprentices, were obliged to fulfill their covenants, and the assent of the master was needed before a journeyman, bound by any agreement, could transfer his services to another master. How unlike 1348 in the trade is 1876. In the ordinances of the Glovers, same reign(1349) similar rules were laid down respecting day-work and night-work, apprentices and journeymen, good materials, bad workmanship, and the defrauding of masters, as in the former trade. We learn that it was a common practice for persons, not of the trade, to entice the servants of folks in the trade and to set them to work in secret in their houses, "and make gloves of rotten and bad leather, and do sell them wholesale to strange dealers coming into the city, in deceit of the people, and to the great scandal of the good folks of said trade." Fines and other punishments followed such and like infringements when the evil-doers were unearthed.

In the ordinance of the Shearmen (shearers of the nap of cloth), same reign (1350), nearly identical rules were laid down for observance as in the two preceding trades. There is one point, however, worthy of notice in respect to the shearmen, which is stated thus:—"Whereas heretofore, if there was any dispute between a master in the said trade and his man (varlett), such man has been wont to go to all the men within the city, of the same trade, and then, by covin and conspiracy between them made, they would order that no one among them should work or serve his own master until the said master and his servant, or man, had come to an agreement, by reason whereof the masters of the said trade have been in great trouble, and the people left unserved." It was ordered in future such disputes should be settled by the wardens of the trade, and workmen not submitting to be tried before such were to be arrested by a sergeant of the Chambers at the suit of the wardens, and brought before the mayor and aldermen. Punishment followed at their discretion. The "covin and conspiracy" among the shearmen and other trades was nothing less than a "strike," and previously to 1350, and down to our own time, history has been continually repeating itself. In the same year we find a petition presented by the master shearmen of the trade respecting the scale of wages. They allude to the former ordinances, and say they are well contented therewith, "Save only that they desire that they may have their servants and journeymen at the same wages that they used to have; for in old times they were wont to have a man to work between the Feast of Christmas and Easter, at 3d. per day and his table, and between Easter and St. John at 4d. per day and his table, and from St. John to the Feast of St. Bartholomew at 3d. and his table, and from the Feast of St. Bartholomew to Christmas, in the case of a good workman, at 4d. and his table, for day and night. And now the said men will not work otherwise than by the cloth (piece-work or a certain price for a certain piece of cloth), and they do greatly hurry over the same, but they do great damage to the folks to whom such cloths belong, by reason whereof the masters in the said trade have great blame and abuse, and take less than they were wont to do. The masters in the

said trade do therefore beg of you that it will please you [the mayor, sheriffs, and aldermen] to order that the said men may be chastised, and commanded, under a certain penalty, to work according to the ancient usage, as before stated, as a matter of good feeling [*charitee*] and for the profit of the people."

Here we have an early instance of the piece-work system being adopted by the workmen and opposed by the masters, no doubt for reasons well known to themselves. The case of a "good workman at 4d.," points to a system of classification.

It is plain, however, that "scamping" was carried on, and that much bad work was the consequence. It is not stated that the prayer of the master shearmen was granted. The ordinances previously passed in respect to the trade continued in force; they were confirmed by the Chamber, and subsequently by command of the king. Piece-work, it appears, was agreed upon, or a certain price for a certain piece of work, by these ordinances, which were cried at the time through the city.

In the same year, 24 Edward III, 1350, owing to constant disputes, "by reason of masons, carpenters, plasterers, tilers, and all manner of laborers who take immeasurably more than they have been wont to take," a number of regulations and prices in the city were drawn up. These regulations included numerous trades, and settled the rate of wages and the prices of materials, work, goods, victuals, wares, articles produced or on sale. Weights and measures were also taken cognizance of, and any infringement of these regulations were met by certain fines, and in some cases imprisonment and forswearing the city for ever. It would appear that in 1350, when the Corporation moved in the matter of these "Regulations," trade malpractices were rife, and were going on for a long time unchecked, and that the public were the principal sufferers. The workmen of the building crafts seemed to be in advance of their fellows, and were not disinclined to ask, take, or insist upon more wages than what they were wont to take years before. It was a common failing, however, and other crafts followed suit, if they did not, indeed, show the example themselves.

In the articles of the Furbishers, 1350, good workmanship and good materials were enjoined, and scamping punished. No one of the trade was to make in his house, or allow to be made, "pommels or hilts of swords if they be not of good pattern and steel, and the scabbards must be made of good calf leather." False work brought punishment to the found-out offender. Broken swords were not allowed to be repaired or made up again, to the deceiving of the people, nor new work executed for "any great lord or other person" if the workman was not perfect at his craft. Perils, we are told, "may befal the lords of the land and others among the people through false workmanship, to the great scandal of the folks of the trade." Doubtless then, as now, many mishaps occurred through scamped work. Doughty and valiant knights depended on the temper of their broad or narrow gauge swords, and lost their temper or their lives through such dependence. In the 27th Edward III, 1353, a royal mandate was issued to enforce the return of several skilled workmen and laborers who left the king's works at the Palace of Westminster. All persons were forbidden to employ these hands, and receivers of them not yielding them up were to be sent to the Tower of London. This was a royal "strike" with no "lock-out," but a lock-up for those who disobeyed his Majesty's orders.

In the ordinance of the Braelers, *i.e.* the makers of braels or braces (1355), we find the friendly society principle recognised somewhat like that mentioned in connection with the White Tawyers (1346). "If any serving-man of the said trade who has behaved himself well and loyally towards his masters whom he has served shall fall sick, or be unable to help or maintain himself, he shall be found by the good folks of the said trade until he shall have recovered and be able to help and maintain himself." Journeymen in this trade were expected to be skilled in their art, and if any one was found of the calling working who did not know his trade, he was to be ousted therefrom, unless he elected to be apprenticed to learn his trade. Working by night was forbidden, on the

pain of cumulative penalties for each offence. At this trade, too, no one was to be so daring as to set any woman to work at his trade other than his wedded wife or his daughter. We see by this that marriage was no bar in the fourteenth century to the wives of mechanics or other tradesmen working. The wives of working men and master-workmen were then help-mates as well as help-eats. No work was to be done on Saturday by the Braelers, or on the eve of a double feast "after None rung in the parish in which he is residing." Other regulations in the trade were similar to some already described. In the "Regulations" for the trade of masons, 30 Edward III, 1356, we find disputes cropping up almost identical with the ones that exist at the present day in the trade, and which caused more than one "strike" in our memory. The masons who were hewers could not agree with the light masons and setters. One infringed on the other's prerogative or alleged prescriptive rights, and hence there was a settlement necessary to be arrived at before a meeting of the mayor and aldermen, &c. At this meeting certain rules or articles were ordained for the better conduct of the trade, and among others "that no one shall take work in gross if he be not of ability in a proper manner to complete such work." Work in the gross meant wholesale or by the job, lump or contract. Whether looked upon in the light of a large or a small contract this work, by the gross was, after all, little short of piecework, or an estimated or agreed upon price for a certain amount of work. A builder's contract in the present day is worked in the gross. His contract includes piecework, or pieces of work of many trades, but while he is glad to do this piecework at a lump price his workmen resent doing it save at so much per day or hour. Apart, however, from the burning questions on the workmen's side, and the equal dissatisfaction in cases on that of the employer, the "tender" subject is becoming a bugbear to the unprotected public and the architect's clients. It is becoming clearer and clearer every day that many contractors of work in the gross do not carefully or conscientiously estimate. They rather glance at the specifications and drawings and by roughly comparing one job with another previously executed by themselves or their brethren, they dash down a price or prices, hit or miss. If they do not estimate by the rule-of-thumb system, wherefore have we the highest tender double the lowest in jobs ranging from a few hundreds to several thousands? It would appear by these "Regulations" connected with the mason craft in 1356, that piecework was acknowledged as practiced in the trade, and classification also, for these "Regulations" say "that the said masters so chosen shall oversee that all those who work by the day shall take for their hire according as they are skilled and may deserve for their work, and not outrageously." There were other good rules for the guidance of the trade and for the due execution of work undertaken, and those who refused to be ruled or directed for the good of the trade were "chastised by imprisonment and other punishment, that so other rebels may take example by them to be ruled by the good folks of their trade."

We have not exhausted our subject, for in connection with other of the building trades untouched and outside them, there are points deeply suggestive and worthy of reproduction and particularization. Between the trade guilds of 500 years ago and upwards and the trade unions of to-day, though there is much difference, yet a great deal of the spirit, the practices, and malpractices in the former survive in the latter. Trades are not now as exclusive and hedged-round as were the crafts of old; still there is a spirit of exclusiveness rampant in the unions.

A NUMBER of engineers and architects, interested in the construction of railway stations, met together at the Paddington Station, recently, to view and examine the ridge and furrow-glass roofs put up for the Great Western Railway Company, on Mr. Rendle's new system. They are very light and elegant in appearance, and contrast very favorably with the old roofs. The system has been so successful that the patentee has received instructions from the company to cover the stations at Cardiff, Swansea, Plymouth, Neath, Bath, Landau, and several other stations.

LEVEES AS A SYSTEM FOR RECLAIMING LOWLANDS.

By GEORGE W. R. BAYLEY, C. E.

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Levees, or embankments, or dikes as adjuncts to systems of reclamation, drainage and irrigation, have been in use since the very earliest times.

The Egyptians, Assyrians, Babylonians, Romans, Hindoos, Chinese, and other nations, built dikes and dams for reclamation, and leveed canals for drainage, irrigation, and navigation. It has been said that "irrigation was the first application of science to agriculture," but, it would seem that reclamation must have preceded irrigation and drainage. It is said that the ancients "excelled in the management of dikes and dams," and therefore they must have known the value of the fertile soil peculiar to alluvial plains, and its luxuriant productiveness when reclaimed, drained, and irrigated where necessary.

The remains of ancient works, built for purposes of reclamation and irrigation, and their vast extent in some countries, excite our wonder. With compulsory labor, under despotic governments, it was practicable to do then what would not be undertaken now. Herodotus says that Menes, the first known king of Egypt, about 2700 B. C., "founded the city of Memphis, after he had diverted the course of the river Nile, by raising a dike," probably to close an old channel, and it seems to be well established that levees, to confine the waters of the Nile and regulate irrigation, were in use at least so far back as the reign of Menes. During each successive dynasty afterwards the system was elaborated and perfected. It is probable that for many centuries before the age of Menes —or the earliest historical epoch—the work of reclaiming and cultivating the Nile valley lands had been progressing, and that it increased with the population and as the necessities of the people required more land for cultivation.

The famous lake Moeris, and the great canal known as the Bahr Yoosuf, or river of Joseph, and other works, including most of the raised mounds upon which cities and villages were built, were constructed when Egypt had become an empire. Sesostris, it is said, dug canals all over the delta of the Nile. Lake Moeris and the Bahr Yoosuf, (the latter, which extended for about 350 miles parallel with the Nile, was, probably, for the most part, at least, a former channel of the Nile,) were used for navigation as well as for regulating and prolonging the irrigation of the adjacent districts, by retaining water after the subsidence of the annual river floods.

For a distance of 500 miles above Cairo, the Nile valley averages ten miles in width, and is divided into a series of basins by means of levees, along the river front as well as away from it. Near Cairo the river levees are from twelve to fifteen feet in height; twelve feet in width at top, and but slightly elevated above the high-water line. The water to moisten and enrich the soil is not permitted to flow unregulated over the river banks, but conveyed by canals and sluices to where it is wanted; it is there retained within leveed areas, so long as wanted, by closing the outlets. Egypt being a rainless country—or nearly so, except near the sea-coast—without forests, irrigation and the fertilization of the soil by the mud-bearing waters of the Nile, is an indispensable necessity. With regular irrigation, independent of the flood season, three crops annually may be cultivated. Improved pumping machinery is now much used in Egypt for this purpose. Much more dependence is placed in methods of obtaining water now than formerly, and less in the canals and reservoirs, which are neglected and suffered to go out of repair.

It is probable that the system of leveeing had its origin in Egypt. The Assyrians and Babylonians, in the valley of the Euphrates and Tigris also adopted a system of reclamation and irrigation by means of levees and canals, and of leveed areas or basins, and reservoirs to enable them to cultivate their river alluvial lowlands. The teeming population of Nineveh and Babylon, in ancient times, required all that these fertile alluvial

plains, under the most elaborate system of agriculture, could be made to produce. In that dry climate, this could only be accomplished under a system of leveeing and irrigation.

The valley of the Euphrates, like that of the Nile, had been subject to annual inundation, but Queen Semiramis, it is said, "prevented the overflow by the erection of stupendous mounds or dams along the banks of the Euphrates, and henceforth the land was irrigated by hand and by engines. The entire territory was intersected, like Egypt, by numerous canals, the largest of which could be navigated by ships, and stretched from the Euphrates to the Tigris."

It is related that Queen Nitocris caused to be excavated, above Babylon, an immense reservoir, and that she turned the Euphrates into it, temporarily, in order that piers of stone, for a bridge to connect the two portions of the city of Babylon—built on each side of the river—might be constructed in the river when so drained. Along both sides of the river, where it flowed through the city, walls of baked brick, provided with brazen gates opposite the streets, and connected with the great outer walls, served as levees, and the banks of the river were lined with burned brick.

Cyrus took Babylon by diverting the Euphrates into the great Nitocris reservoir, at night, thereby enabling his army to march along the river bed, from above and below, to and through the street river gates into the city; the river gates having been left open during a great feast and carousal made by Belshazzar, the king.

In China the immense and crowded population, of necessity is compelled to cultivate every available square foot of ground, and to make the best possible use of every means of increasing its production. Rice is the great staple crop of large portions of China, and this grain requires for its cultivation leveed areas and irrigation. The vast alluvial plains of the Yang-tze-Kiang, or Blue River, and of the Hoang-ho, or Yellow River, are leveled, irrigated and cultivated. M. Huc says: "The maintenance of the dikes on Yellow River is intrusted to a special board, which forms in the provinces of Tchi, Chan-toung, and Honan, a body independent of the provincial administration."

In Hindustan, owing to the suddenness and short continuance of the monsoon rains, and the long continued droughts, it has always been necessary to resort to irrigation by means of dikes, dams, canals and reservoirs, for the cultivation of the vast sterile upland tracks of country in Northern, Middle, and Southern India, which were barren only for want of irrigation.

Speaking of the "tank irrigation" system of Madras, Mr. Smith says: "The extent to which it has been carried throughout all the irrigated region of Madras Presidency is truly extraordinary. An imperfect record of the number of tanks in fourteen districts shows them to amount to no less than 43,000 in repair, and 10,000 out of repair, or 53,000 in all.

It would be a moderate estimate of the length for each, to fix it at half a mile, and the number of masonry works, in sluices of irrigation, waste-weirs, etc., at six as an average. These data, only assumed to give some definite idea of the extent of the system, would give close upon 30,000 miles of embankments, sufficient 'to put a girdle around the globe' not less than six feet thick, and 300,000 separate masonry works. The whole of this gigantic machinery of irrigation is of purely native origin. Valleys are taken possession of, and the natural drainage lines flowing through them are checked by embankments sufficiently long to close the gorges, and sufficiently high to retain a volume of water proportioned to the areas of irrigation situated below them. Descending steppes of land are occupied by a succession of reservoirs, the higher feeding the lower from its surplus supply, and the whole forming one connected scheme of irrigation. Dry, basin-shaped hollows have banks carried round their ridges, and supplies were introduced from adjoining rivers by means of special canals; or long slopes, where the fall is considerable, have portions embanked more or less regularly on three sides."

Among the most ancient of these tank reservoirs he mentions the "Poniary, in Trichinopoly, with its embankment of thirty miles in length, and probable area of sixty to eighty square miles, now lost

to the community, and the Veeramun tank, with its twelve miles of embankments, and thirty-five square miles in area, happily still in full operation." He considers the Chumbrumbankum tank as "one of the finest in Madras Presidency." Its area is nine and a half square miles; its volume may be estimated at 3,000,000,000 cubic feet of water. It maintains a sheet of rice cultivation nearly 10,000 acres in extent.

Mr. Hewson says that one of these tanks, constructed in the island of Ceylon, was formed "of huge blocks of stone, strongly cemented together and covered with turf, a solid barrier fifteen miles in length, 100 feet wide at base, sloping to a top width of forty feet, across the lower end of a spacious valley."

According to Mr. Smith, the Mogul Emperor, Feroze Toghlak, in the fourteenth century, built "fifty dams across the river to promote irrigation, thirty reservoirs for irrigation, 150 bridges, 100 public baths," etc., and the first canal of which there is any record in north-western India.

The British Government, since its conquest of Hindustan, has enlarged and improved the systems of irrigation by means of tanks and canals throughout all India. The Great Ganges canal, commenced in 1848, was to be with its branches, 900 miles in length, and capable of furnishing irrigation for about 4,500,000 acres of land.

In India levees or embankments, carried across the bed of a river or a valley, are termed "bunds."

In Italy, the system of leveeing or embanking rivers, and of reclaiming lands for cultivation, has been in successful operation for many centuries. The Adige, the Tiber, the Arno, the Reno, and the Po—particularly the latter—are well-known examples. Paul Frisi, in the preface to his work on "Rivers and Torrents," printed at Florence in 1770, claimed that "hydraulic architecture arose, advanced and almost attained perfection in Italy, where they have written on every point connected with the theory of torrents and rivers, the conducting and distribution of clear and turbid waters, the slopes, the directions, and the variations of channels, and, in a word, on the whole range of hydrometry and hydraulics."

We obtain from Frisi's work very interesting information respecting the observed effects of leveeing the Italian rivers, some of which, though undoubtedly reliable, correct, and applicable to all sedimentary rivers is not yet known or appreciated by many modern engineers. The Italian engineer demonstrated that torrents, which carry down stones and gravel, can not be successfully circumscribed by or between levees or dikes, for their beds will rise and continue to rise, by the accumulation of stones and gravel in them; that the lower portions of rivers carrying and flowing through sand and earth only, which make and shape their own beds and banks, can be leveed safely, without elevations of their beds or surface as the result of the increased quantity of water confined by levees to the channel; that "derivations" or outlets are useful for the purpose of permanently lowering the flood line in such portions of a river, and that a division of the waters of such a river into more than one channel results in an elevation of the beds and high-water lines of the divided channels.

Frisi says: "The Po, which, formerly divided into several branches between Placentia and Parma, had converted a considerable part of Lombardy into a marsh, has been circumscribed by dikes and confined within a single channel of a suitable depth," without any increased elevation of surface; "whereas the Great Rhine, divided and subdivided as it is in Holland, has considerably elevated the bottom of its bed; and, whilst it renders the situation of the adjoining lands daily worse and worse, is threatening them incessantly with utter destruction.

"The first division of the waters of the Rhine was begun under the Roman generals Drusus and Corbulo; it was afterwards continued in later ages by a great number of subdivisions. This great multiplicity of channels, though productive of very great advantages to the navigation and commerce of Holland, draws after it very fatal consequences. The waters, divided into so many branches, lose their rapidity and strength which are required to sustain and push

forward those heterogeneous substances wnich they transport. The constant rising of the bottom renders the draining of the waters from the fields more difficult, increases the expense of the necessary embankments, and always augments the damages which these extensive lowlands suffer when the dikes break. To secure that part of Holland which lies between Rotterdam, Utrecht, Amsterdam, and the ocean, it was proposed, in 1754, to form in the Leck, which is another branch of the Rhine, a cut with sixteen sluices, by which a part of the water should be discharged into the Mernva, which is the junction of the Meuse with the Wahal." The engineer Gennette, says Frisi, opposed the proposition to make an outlet, claiming "that the proposed alteration would avail nothing towards the diminution of the height of the floods," and advised, "in lieu of it, to remit all the waters of the Great Rhine in the ancient branch of the Issel, and in this manner to conduct them by the shortest road to the sea." He maintained that "by the union of all the waters their rapidity would be increased, whilst the amplitude—width—of the sections would continue the same; and that, in consequence, the waters would have more strength to deepen their bed and to prevent those deposits that are successively made in it. He supports his opinion by the directly contrary effect produced from the actual divisions of the Rhine; and he adds that this river, before it is divided in Holland, receives at Mentz the Mayn, whose flow is nearly as great, without its being possible to observe any perceptible difference in the dimensions—width—of its bed. The Samoggia and the Lavino, in Italy, running near each other, and having almost the same course, their floods always come down at the same time. Thus, although the quantity of water is increased nearly one-third in the Samoggia, after the injunction of the Lavino, as has been already said, and although the slope of the bottom is considerably diminished in the Samoggia, nevertheless the height is less, and the whole section very little larger than before. The operations carried on in the Gaina were not less exact; yet, although it increases by nearly half the body of water in the Quaderna, it sensibly augments neither its height nor magnitude—width of its sections. We have, besides, several other examples of running streams considerably augmented, in quantity of water, without any visible increase of their height or breadth.

"What has been observed in the conjunction of rivers is also seen in their derivation—reduction of quantity by outlets—or division, where it often happens that in diverting from the principal channel a considerable body of water, that which is left behind is not visibly diminished, either in height or in breadth. The canal made by order of the Emperor Nerva, to draw off the superfluous waters of the Tiber, at the time of its greatest freshets, did not contribute in the smallest degree to prevent the inundations, as Pliny has assured us in his letters. The two relieving sluices that Vincent Viviani caused to be made in the Celone, which is a tributary of the Chiana, have caused the filling up and the loss of the principal trunk." Speaking of the Adige, it is said "*that all derivations—outlets—made in that river have only produced a heightening of its bed, and thereby rendered its floods more dangerous.*"

Other quotations of the same purport might be added, did space permit. Frisi says that "It is an hydrostatical paradox, commonly taught by Italian authors, and uniformly confirmed by experience, that you do not diminish the height of the waters in great floods by lessening the quantity of the water." His meaning obviously is that outlets—or "derivations," as he terms them—will not permantly reduce the flood line of a sediment-bearing or turbid river. Guglielmini announced that "the greater the quantity of water that a river carries, the less will be its fall," or surface slope; and he adds, that "the greater the force of the stream, the less will be the slope of its bed."

We understand that the production of steel increased in France last year to the extent of 21,000 tons, as compared with 1874. This increase was, however, more feeble than in any preceding twelve months, and it was attributed almost exclusively to the increased use of steel rails.

RAILWAY SPEEDS.

From "The Engineer."

A SOMEWHAT unfortunate tendency has always been manifested by a few of the leaders of public opinion to attribute railway accidents to high speeds. If a collision takes place, we are assured by these gentlemen either that it would not have taken place at all or that the consequences would have been insignificant had the speed been slower. If a train runs off the rails, the cause of the derailment is at once found in the high velocity at which the engine was moving at the time. Railway companies are told in very plain terms that it is a suicidal policy to drive locomotives at speeds much exceeding thirty miles an hour; and we are gravely informed that the risk incurred by the passenger who travels by an express train can hardly be exaggerated. Hitherto the effect of such arguments has been very trifling. The public like to travel at high speeds, and they patronize companies who supply what they wish to have. But there is some danger that a warning often repeated will have the effect of creating a groundless alarm; and we should fail to discharge our duty if we did not point out that while high speeds are not necessarily unsafe, it is certain that slow speeds will not prevent accidents. It is worth while to put these truths clearly before our readers, and to explain why they are truths and not empty assertions; but, in the first place, we must call attention to the fact that any considerable and extended reduction in the velocity with which railway companies conduct their traffic could not fail to act prejudicially on the interests of the community. On our great main lines trains are now run at the closest possible intervals, consistent with safety, during certain hours of the day and night. An important reduction in speed must of necessity be followed on such lines by a reduction in the number of trains. Time and space intervals are, in a word, so intimately connected with each other that it is impossible to sever them. Thus, if ten minutes intervene between the starting of two trains, say from Euston, both running over the same road as far as Rugby, it is obvious that if they both move at thirty miles an hour the space interval between them will be half what it would be if both ran at sixty miles an hour. It is quite true that, in theory at all events, the space between two fast trains ought to be greater than between two slow trains; but when we come to deal with the practical working of railways, it will be found that the faster trains are run the more quickly can they be started in succession when the runs are long. The result is that the higher the speed the greater is the capacity of a line, because the shorter is the time during which each train occupies the road. It is not necessary, we think, to explain this point further. It will suffice to say, as a matter of fact, that railway companies are able to get much more work out of the roads at high speeds than they could at slow speeds. Apart from all such considerations, moreover, is one paramount to all others. The public wish to travel fast, and they patronize the lines on which they are conveyed most quickly. A general reduction in the rate at which trains now travel would seriously disorganize trade arrangements. It would infallibly lead to a diminution in the amount of accommodation supplied to the public, and it would militate against the despatch of business. It is possible some of our readers may be skeptical on such subjects. We would ask them to turn to, we will not say their own continental experience, but that of Germans, Frenchmen, Austrians, Russians, and Italians, and they will find the utmost unanimity in the opinions expressed. They will meet but one reply—namely, that continental railway speeds are, as a rule, much too slow. The inconvenience of slow speeds has been so keenly felt, again, in the United States, that most determined efforts are being made on all the principal lines in North America to obtain more rapid transport. Within the last few years "lightning expresses" have been put on between the principal cities, and American railway traveling bids fair to become the fastest in the

world. If the opinion of the great mass of business men is worth anything, then high railway speeds are necessary, and should not be lightly abandoned.

Are high railway speeds unsafe? On the reply which can be given to this question everything depends after all. Our answer, and that of every engineer who has given the subject due consideration, must be that fast trains are quite as safe as those which run slowly, provided the road and rolling stock are fit for high velocities. Of course if a road is bad, or the rolling stock imperfect, a train cannot be run safely at a high speed. Our contention is, however, that no difficulty is experienced in making roads, engines, and carriages which are suitable and safe for any velocity up to, say, seventy miles an hour. There are only two distinct classes of accidents which can follow as a consequence of high velocities. The one is the breakdown of some portion of the rolling stock, such as a spring, or an axle, or a tire; the other is the running of the train off the rails. Now a reference to Board of Trade reports shows plainly enough that fast trains do not break down more frequently than slow trains. Tires burst just as often at speeds of thirty-five or forty miles an hour as at higher velocities. The axles of goods trains give way much more frequently than those of any other trains, and they certainly never attain exceptionally high speeds. In a word, although it is true that fast trains do break down now and then, it is impossible to prove that these casualties are a natural consequence of the speed at which such trains are driven. We may assume, in short, that the risk incurred in running an express train is not due to anything inherent in the train. The real source of danger lies in the road, and it is indisputable that it is extremely dangerous to run at high velocities over bad and weak roads, especially with engines which are not well balanced, or which tend to oscillate or "wander." Turning once more to Board of Trade reports, we find that in almost every case of derailment the cause is easily to be found; and that it lies in nine cases out of ten in some defect in the permanent way. One disastrous accident of the kind ensued from a defect in the points at an important station. Another train not long since ran at slow speed off the rails at a diamond crossing. A little careful examination showed that a guard rail was out of place, and that the flange of the leading wheel of the engine consequently struck the point of the crossing, and mounting it, got off the road. We could cite such instances by the dozen, but we can only call one serious case of derailment to mind where the cause lay wholly in the engine. This occurred a few years since on the Great Eastern Railway, and was due to the breakage of a transverse leading spring. We have every reason to believe that the engines and carriages on all our main lines may be run with perfect safety at maximum speeds over good roads; but it must be admitted that the engines on some lines require better roads than those on other lines.

Thus, for example, while we are quite willing to concede that Mr. Pearson's great tank engines on the Bristol and Exeter line could be run with perfect safety at as much as seventy miles an hour on a perfect track, we hold at the same time that they are eminently unsuitable for a bad road; and that they are more likely to run off such a road than locomotives of a different construction, and with a less load than eighteen tons on a single pair of driving wheels would be. If it can be shown that the great mass of accidents results from the imperfect condition of the permanent way, it is absurd to argue that slow speeds should be adopted to secure safety. The true remedy lies in the improvement of the road, and not in the adoption of minimum velocities.

We have said that a reduction of speed would not prevent derailment, and we repeat the statement. The first and direct result of a general reduction in speed would be a diminution in the sum expended in the maintenance of permanent way. The worst roads in the world are those in which the speed is least, and off such roads trains are constantly running. When railway companies run fast trains they are compelled to maintain a high standard of efficiency both in their roads and in the rolling stock. If we remove the stimulus, we shall have less exertion, the character of our lines will fall off, the efficiency of all the

departments will be diminished, and we shall have extra risk instead of additional security. We see with regret that the Great Western Railway Company have resolved to run the "Flying Dutchman" at but forty miles an hour over the worst parts of the Bristol and Exeter road. Our readers may rest assured that if a line is not fit to carry a heavy engine at sixty miles an hour, it cannot be traversed by the same engine with safety at forty miles an hour. The true policy of the company should be to render their road as good as it can be made. It is a serious confession of weakness to seek a nominal safety in a reduction of speed. The daily records of our great lines prove that maximum velocities can be maintained over a good road with perfect safety, and that on a bad road danger is continually incurred. The duty of those who would influence public opinion lies not in recommending the acceptance of low speeds and their inevitable consequences—bad roads—but in urging railway companies to permit those who serve them to maintain roads, engines and carriages in that high state of efficiency which is so dear to the hearts of English railway engineers.

AIR AND VENTILATION.

From "The Building News."

So many theories have been put forward of late years upon the subject of ventilation that architects may be excused for not having propounded a method that shall be universally applicable to all buildings. The *plenum* and *vacuum* ideas have been ridden to death by different authorities on the subject: costly schemes and systems have been introduced into our large buildings with a degree of success scarcely proportionate to the outlay. The mechanical devices which have been proposed have generally been prompted by interested motives, or have been the nostrums of advertising manufacturers, and to such an extent has this been carried, that architects have a fair ground to inquire upon what principle they are required to give adhesion to this or that mode. The simplest methods are the best, and if by any arrangement of apertures we can produce the necessary change or current of air—that displacement necessary for health—we may consider the problem solved. But the amount of air required for respiration has been so variously estimated, that it has been next to impossible to lay down any rule. Thus one authority tells us that fresh air must be admitted at the rate of about 4 cubic feet per minute for each individual in the apartment. Another writer puts the quantity at 2.39 cubic feet. But in many of these calculations the quantity of air required for the combustion of the fire-grate and gas burners is not taken into consideration.

A little brochure, entitled "Fresh Air in the House," by Mr. Curtis, puts the matter in a nutshell, enters concisely into the first important question of supply, and gives us some useful information. In estimating the constant quantity of air required, the measurement of the volume of air used in the vital function of respiration is necessary. The spirometer measures accurately the three volumes of air displaced in breathing, or the most complete voluntary expiration following the most complete inspiration or vital capacity. The vital capacity volume is modified by height, attitude, weight, age, and disease. Dr. Hutchinson says, regarding the measure of volume as affected by height:—"The vital capacity is the same in all men of the same stature, quite irrespective of the size of chest." The volume differs according to the height in an arithmetical ratio. "Thus a man five feet eight inches can breath 230 cubic inches of air (at 60° Fahr.) at one expiration, and a man an inch taller 238 cubic inches by a similar effort," whereas a man an inch shorter can only breath 222 inches, being eight inches less. The following law is deduced from these facts:—"That in the erect position, for every inch of stature from five to six feet, *eight* additional

cubic inches of air at 60° Fahr. are given out in one volume by the deepest expiration immediately following the deepest inspiration." This rule was the result of upwards of 4,000 experiments upon men of all heights and classes. The experience points to a minimum limit of sixteen per cent below the mean for health. The mean number of respirations per minute in the case of 1,407 healthy males was found to be eighteen, and the pulsations seventy-eight. Then, if we take 230 cubic inches for the quantity of air necessary to a man of medium height for each breath, and multiply this by the number of respirations per minute, we shall get something like the quantity required, and which will give us 2.39 cubic feet as the fullest measure. Taking an ordinary sitting-room fireplace holding seven pounds of coal, and requiring 4.032 cubic feet of air to consume it —supposing the combustion to take two hours—we get a rate of consumption of 33.6 cubic feet per minute, or a consumption equal to eleven persons. Mr. Curtis, the author of the treatise above named, sums up the amount of air required per minute in an ordinary sitting-room, with fire and gas, and occupied by three persons, as follows:

3 persons require	9	cubic feet.
1 fire "	33.6	"
3 gas burners	54.0	"
Total.....	96.6	cubic feet.

The door is allowed to supply a quantity equal to two windows, or thirty-two feet, which leaves sixty-four feet to be supplied, and which must, under ordinary circumstances, rush through all crevices and openings at a velocity productive of draughts and their concomitant evils. The next question is the means by which this quantity of air can be supplied at such a rate as to avoid draught. As air expands by heat it is obvious that the greater the difference between the external and internal air of a house the greater is the tendency of the heated air to rise. Air traveling at the rate of eighty-eight feet per minute is hardly perceptible, and if the openings have an area of 108 square inches, the quantity of air required will be easily admitted. The author says, "To permit of the passage of this 96.6 feet into the atmosphere, the aperture may be reduced in the proportion of one to three. Taking away windows and door as useless for this purpose, the area of the exit or exhaust-pipe will be ninety-six square inches. This close calculation should be modified in practice. The openings for the admission of air should have at least an area of 144 square inches, or one square foot, while, for the eduction pipe, the area should not be less than ninety-six square inches for each 2,000 feet of space in a room of this size." Thus, a proportion of three to two is established; in fact, we have a supply of air on the plenum method by which the fresh air enters the room under pressure and presses out the vitiated air. Mr. Curtis proposes the siphon principle as the means of supply and egress; or, in other words, a flue or pipe from the top of building to the basement, in the piers of the front and back walls, and other flues to operate as exhaust or eduction flues in the chimney-stacks, or near some heated flue opening at the ceiling levels of rooms. The descending pipe, with openings at the level of the floors, constitutes, with the extracting or exhaust pipe, an inverted siphon, for the air of the room becomes a part of it. The air pours down one leg and out of the shorter one, just in the same manner as water poured down the longer leg of an inverted syphon will flow out of the other leg. The eduction or exhaust pipe is really the shorter leg, down which no cold air can flow, because the air in it is of a higher temperature, its opening being close to the level of the ceiling. Thus we have a constant current maintained by the simple hydrostatic law of one column of fluid acting against a lighter column, without cost of mechanical contrivance or the aid of steam or heating power. The plan thus proposed is not new; it has been know for centuries. We know of double flues acting in this way that have been found in the refectories of monasteries; in fact the principle has been lately adopted in the construction of various kinds of artificial apparatus for ventilation. Such are Chowne's "air siphon," which is an inverted siphon, and acts on a similar principle to that described above; and Watson's "double-current ventilator," consisting of a tube or trunk, opening at the ceiling, divided by a diaphragm.

McKinnel's invention, consisting of two concentric tubes, the inner one, being the longest, acts in the same way, the longer tube being the exhaust pipe, and the shorter and surrounding tube the inlet. These inventions are more or less effective according to the difference of temperature between the two columns of air. It has been found that sometimes both these tubes act as exhausters, but of course this mainly depends on the fact that a large influx of air is permitted below. No doubt the siphon applied to the top of a room has little effect in the manner intended if there are openings below, and its action can only be maintained when all such apertures are closed. It is then only the principle comes into play, and it is then only that it is chiefly required. The same may be said of the flue system proposal. If the shorter pipe or flue leading from the top of the room is not sufficiently warmed by being placed near a flue, so as to create an upward tendency in its column of air, a state of equilibrium will ensue, or a reverse action will be set up. The longer leg or pipe may possibly become so much warmer that, instead of a descending current being established, an ascending one will take place, and the exhaust pipe will supply. It is very seldom, however, such a condition of things can exist, as the longer tube or column of air being always, under equal temperature, heavier than the shorter one, motion must ensue. Wherever practicable, therefore, it is desirable to place the exhaust pipe by the side of a flue constantly or generally warm—as the kitchen flue—and to bring the supply pipes down the outer walls or piers on the coolest side of the house.

It is desirable also that the supply channels should have a larger area than the exhaust pipe or outlets. The proportion we have mentioned seems a desirable one. Tredgold recommends that the lower openings should be double the area of the upper ones, and be divided to break the current. Unless this precaution is taken by the architect in proportioning his apertures the current of cold air will not be so efficient in displacing the hotter air. Sometimes, indeed, we find the outlets much larger than the regulated inlets. The consequence of this is that a current of colder air will descend through the outlet, which, in fact, will become divided by the two opposite currents, these will intermingle with each other. It is upon this fact that Watson's double-current ventilator was invented. It may be as well to remind some of our readers that the velocity of discharge per second through tubes of this kind is eight times the square root of the difference in height of the two columns of air in decimals of a foot. A deduction of one-fourth of this for friction will be the efflux.

The system re-introduced to the public through Mr. Curtis's pamphlet is one that we can confidently recommend to the profession. Into the details of the arrangement we have not space to enter here. Wooden or metal pipes (the latter are best) may be used for the supply tubes: for the exhaust pipes iron or zinc pipes should be used. The fresh air may be introduced at the skirtings or dado, or just above the heads of people in assembly-rooms through perforated panels, while the open or perforated cornice appears to us to be the most desirable means for the egress of the gases. Sunlights are useful in producing an upward current, and a gas jet kept burning in the eduction flue of a large room may be judiciously employed. Two methods should always be before us in ventilation, either of which we can adopt, according to circumstances. The first is that of extracting or drawing off the vitiated air, the fresh air filling the vacuum; and the second, the plenum system, that of forcing air in, the vitiated being driven out. But for either of these modes we must provide means. To depend on windows and doors may do very well in ordinary houses, not too crowded, but it is unscientific, to say the least; and if we desire to make our buildings perfect in scientific and artistic arrangements, we must take some pains in proportioning these apertures so that a constant current may be going on when our buildings are densely crowded and closed.

THE aggregate extent of railway in operation in France at the close of last year was 12,376¼ miles, as compared with 11,950 miles at the close of 1874. It follows that the extent of new line opened in France in 1875 was 426 miles.

MINERAL RESOURCES OF JAPAN.

From "Iron."

The Japanese Commission to the Centennial Exhibition has lately issued a work modestly termed an official catalogue, but which is really very much more, since, out of a hundred and thirty pages, thirty only are given to the list of articles, and the remainder are devoted to a series of excellently written descriptions of the principal resources and industries of the country. From this catalogue we make the following extracts, beginning with the subject of

Mining and Metallurgy.—Very little is known about the origin of mining in Japan. It is, however, a fact that several mines were being worked during the latter part of the eighth century, and the large number of old abandoned adits, which are to be found in the metalliferous districts, leave no doubt as to the fact that mining was in a flourishing condition centuries ago.

The system of working mines has changed but little since olden times, and consists simply in driving one or several adits from places where a vein or seam appears on the slope or top of a hill; the vein is followed as far as possible, and when necessary, lower adits are driven, until in the end it is found impossible any longer to overpower the water with the very imperfect machinery used for pumping and draining. Many mines have had to be abandoned after a longer or shorter period of prosperity, solely on this account. In certain instances great efforts have been made to avoid this misfortune, and adits have been driven for the purpose of draining off the water. Thus in the lead mines of Hosokura, in the province of Rikusen, a draining adit may be seen of 8,370 feet in length; nevertheless the mine has been almost entirely abandoned, and the actual working places are at present far below the level of the water adit in question. In the mines of Udoge, where the rock is very soft, a water adit thirteen feet high and ten feet wide was commenced a few years ago. Ever since the earliest times the timbering of the adits has been known and effected with all the necessary skill; and as the wood is both abundant and cheap in most places, it has not been spared. The dimensions of the adits vary greatly; in some mines they are so narrow that it is almost impossible for a full-grown person to pass through, and consequently children have to effect the transport of the mineral. The latter is usually packed in strong sacks, made of matting, which are fastened to the child's back by means of a rope. In many places the passage becomes so low that the child has to crawl along on all fours, dragging the sack of mineral behind him. The ladders used for getting from one adit to another on a different level are simply trunks of trees with steps cut into them.

The means employed by the miner for attacking the rock consists merely in the use of hand tools, namely, the pick, the gad, the hammer and chisel. Gunpowder has only been brought into use for blasting purposes in latter years, and its introduction is chiefly due to foreigners. The apparatus used for removing the water is composed only of small wooden hand-pumps, buckets and occasionally of a kind of water-wheel with scooping paddles, and moved by treading; the water pipes are either made of bamboo or wood. As regards the ventilation of mines, it is often realized with more or less of perfection, by connecting two adits of different levels, and in some cases by running an air channel, made of wooden planks, throughout the whole length of the adit, so as to allow the air to circulate through the adits and this channel. In the lowest adits, however, the absence of sufficient ventilation has in many cases caused them to be abandoned or else to be worked on a very small scale only. The lighting in the mines is either effected by torches of dried bamboo or oak wood, which latter is beaten until it becomes soft enough to burn easily; or by iron lamps in the shape of saucers with a double suspension. Sometimes the lamp consists merely of a kind of murex shell containing vegetable or fish oil. The wick is made of the pitch of soft rush

(*juncus effusus*), which is also used for wax candles and ordinary lamps.

The annual production of the mines of Japan, in gold, silver, copper, iron, lead, tin, coal and coal oil was valued in 1875 at $3,687,275.

Of late years the Government has made great efforts to improve the condition of mining and metallurgy, the principal shortcomings of which are:—(1) The insufficiency of machinery for pumping out the water; (2) the imperfect system of attacking the rock with only hand tools, which, together with the custom of leaving the mine to be worked entirely by contracting miners, without any system and under no control, has not only the effect of causing a great part of the vein to be left untouched, but also in many cases the future of the mine has been endangered by the total absence of any well combined plan; (3) the imperfection, and, consequently, the expensiveness of the processes employed for dressing, preparing and smelting the ores. Some mines, however, such as the Takashima coal mines, near Nagasaki, are now being worked according to the modern system and are provided with the necessary steam power. The working of several other mines is being improved in the same manner, and the new works are already in course of erection at the silver and copper mines at Ikuno, Sado and Ugo. The Government mining department has also commenced the construction of several high furnaces for the smelting of iron ores.

It will be observed that an excellent field is here open for improved mining inventions of all kinds.

Minerals, Ores, &c.—The veins of gold and silver ores in Japan are generally composed of quartz, native silver, silver ore (argentite and antimonial silver), containing more or less gold and iron and copper pyrites, occasionally mingled with blende and galena. The most important, and almost the only iron ore worked till now is the magnetite, found either in the shape of solid masses or in that of sand. In general the magnetic ores contain from sixty-two to sixty-five per cent. of metal. The magnetic sand and the solid ore are the only materials used for smelting iron; however, iron glance and brown hematite, with fifty-six to sixty per cent. of iron ore, are also found in Japan. Copper ore is found in many places, and may be considered as a rich ore, since it contains on an average from ten to fifteen per cent. of metal. It is composed mostly of copper pyrites, together with more or less iron pyrites, and is found chiefly in clay slate. The principal mines are situated in the northern part of the island of Nippon, but ores are also found in more southern provinces, as, for instance, in Bichiu. Sometimes the ores are much richer than has been stated, and contain twenty-five to thirty-five per cent., even up to fifty-five per cent. of copper. The lead ores which are found in Japan are mostly galenas, with forty to eighty per cent. of metal, and sometimes a small quantity of silver. Tin ore is found in Satsuma, Suwo, and Bingo. In latter years, attention has been drawn to other minerals, such as gray antimony and bioxide of manganese; but they are, as yet, without great importance. A cobaltiferous mineral, which is found in the shape of small pebble conglomerates in the bed of certain rivulets, has been known for many years. After the raw material has undergone a certain process of powdering, washing, and calcining, it is used for blue porcelain paintings.

Coal, Asphalt, Petroleum.—The most important coalfields are those in the north-west of the island of Kiushiu, in the district of Karatsu; and also in the island of Takashima, near Nagasaki. The total yield of the Karatsu district may be estimated at eighty to ninety tons daily, which is sold at neighboring ports at $4 to $5 per ton. The working of the rich seams in the island of Takashima, about eight miles west of Nagasaki, has been commenced on the modern system, with improved machinery. This mine, actually the property of a Japanese company, is now very prosperous, and produced 78,000 tons in 1874. In the island of Amakusa, on the west side of Kiushiu, a sort of coal is found, which is very much like anthracite. As the industry of the country is being developed by the introduction of new methods and machinery, so will the demand for mineral combustibles increase, and mining will be effected on a much more extensive scale.

Petroleum is found in the districts to the north-west of Tokio, as, for instance,

in Yechigo, Shinano, Ugo, &c. In the first of these provinces oil was discovered 300 years ago; and it has always been counted amoung the seven wonders of Yechigo that a natural combustible gas issued from the ground in certain places, and could be brought through bamboo pipes into the interior of the houses and used for illuminating purposes, as it is now used for heating the small stills for refining the crude oil. Although the presence of the oil has been known for a long time, the people of the country began to use it only forty-six years ago. Since then, no less than 508 wells have been sunk.

Building Materials.—Although building stones are by no means scarce, yet they have been seldom used for houses, but mostly for foundations, temple stairs, gateways, sea walls, and battlements, which latter are sometimes of enormous extent: as, for instance, in Tokio and Osaka, where some granite stones of thirty feet in length by eighteen feet can be seen. The battlements and walls are generally made of well-dressed blocks of irregular shape, built up without the use of mortar. The chief materials used for these different purposes are granite, trachyte and trachytetuff.

All kinds of colored mixtures of sand, clay, and lime, and mineral colors, are prepared for plastering the inner walls of the houses, and a very fine black stucco is used for the exterior of the fireproof warehouses. In order to give the plaster more solidity and coherence, paper fibre (prepared by boiling old paper) and the gluish decoction of a *fucus*, called *fu*, are mingled with the powder.

Clay, Kaolin, Silex, &c.—Minerals used for pottery of all kinds, such as clay, kaolin, silex, &c., are very abundant in Japan, and are spread over all the country. In the small town of Arita, province of Hizen, the head center of the porcelain manufacture of Japan, within a very limited circuit, not half a mile in diameter, there are found embedded in the rock at different places, all the materials necessary for the "biscuit," for the coating of the ware before glazing, for the glace, for the *craquelé*, &c., the best being of such good quality that, after being powdered and decanted, it is used without any further mixture for the finest wear—the so-called egg-shell porcelain. In the central part of Niphon, where granite is the principal constituent of the mountains, in the province of Owari, Yamashiro and the island of Awajishima, opposite Hiogo, beds of *petuntse*, very much like the Bohemian material, are to be found. When used for porcelain, this material is mixed with silicious felspathic minerals from other places. A thorough mineralogical and chemical examination of these minerals has not yet been made, but would, no doubt, prove to be of great interest. Graphite has been discovered in Satsuma and Rikuzen; certain very pure samples have been found fit for such purposes as the manufacture of pencils; but in this case it would have to be washed and ground with an addition of clay. Whetstones, grindstones, of all qualities, are very abundant, and are in the hands of every artisan, who, on account of the softness of his cutting tools, is frequently obliged to have recourse to the whetstone. Garnets are used for grinding and polishing hard materials.

ON THE EFFECTS OF IRON MASTS ON COMPASSES PLACED NEAR THEM.

By Staff-Commander E. W. CREAK, R. N.

Proceedings of the Royal Society.

The question of the position of the standard compass on board ship, whether of wood or iron, is one of the greatest importance with respect to safe navigation. In H.M. ships it is one of the principal duties of the Superintendent of Compasses to secure the best possible position for this compass, and when that position has been determined, to ascertain the horizontal and vertical components of the total magnetic force resulting from the iron used in the construc-

tion and equipment of every class of vessel, in order that the correctness of this choice of position may be insured and the facts recorded.

With proper instruments in experienced hands these observations can be readily made; but in iron ships it is a somewhat intricate matter to eliminate the part which the hull plays in producing these forces, from those caused by iron used in equipment, unless observations are made on completion of the hull and afterwards as the equipment progresses. In wooden ships, however, the case is different; for the great mass of the ship being of wood and the iron in detached masses, the latter can be attacked in detail, and the disturbance they cause to the several compasses nearly observed.

Carefully conducted investigations made in different ships on the effects of similar bodies of iron are very valuable to those directing compass arrangements, as they give the necessary information as to how near those bodies may be approached or of necessity avoided.

The effects of introducing iron riders for strengthening wooden ships were in a measure discussed by the late Captain E. J. Johnson in his work "On the Necessity of ascertaining the Deviation of the Compass," where he treats of the diagonal iron riders of the *Encounter* and *Conflict*, but afterwards more fully in the papers which the present Hydrographer, Captain Evans, F.R.S., has written and published in the Philosophical Transactions of the Royal Society, Journal of the United Service Institution, and Transactions of the Institute of Naval Architects. In these papers may be traced in turn the effects of adding steam engines and boilers, iron beams and armor plating; but until lately no good opportunity has occurred for accurately defining the action of iron masts in producing compass disturbance from observation. The case referred to is that of H.M.S. *Undaunted;* and when about to visit that ship in the ordinary course of my duties in the Compass Department, I was directed by the Hydrographer to make a special series of observations of the horizontal and vertical forces at all three compasses, as the lower masts and bowsprit were of iron.

To prepare the way for a discussion of the results of these observations, it appears necessary to give a short history of the two principal vessels mentioned in this paper, and also to go over some already well-trodden ground, whilst taking account of all the iron and the effects on their compasses, until the question of the iron masts alone remains to be settled.

For some years past there have been lying in Sheerness Harbor two wooden frigates of exactly the same build, tonnage and horse-power, namely, the *Undaunted* and *Newcastle*—the only important difference between them being that the *Undaunted* has iron masts, the *Newcastle* wooden. The diagonal iron riders which form the principal portion of the iron used in construction of their hulls are about six inches in breadth, three-fourths of an inch thick, and placed five feet apart at an angle of forty-five degrees with the decks, they extend from about five feet from the keelson on both sides of the ship up to the top sides—the after riders inclined towards the bow, the foremost towards the stern, the two sets meeting and overlapping amidships. These riders, therefore, being separated, are independent magnets, except at the point of meeting just mentioned.

The *Newcastle* was built at Deptford, head S. 73° W. (magnetic), and is a vessel of 3,035 tons and 600 horse-power. The *Undaunted* was built at Chatham, head S. 43° E. (magnetic), and is a vessel of 3,039 tons and 600 horse-power. Assuming the dip at the time of building to be 68°, the after riders of both ships (near which the compasses are placed) were not far removed from the direction of the Earth's Total Force, and would therefore become strongly magnetized, especially those in the *Undaunted.*

A glance at the coefficient C of the standard compasses, given in the Table, shows at once which ship was built in the easterly and which in the westerly direction; and, further, it is highly probable that in the *Newcastle* the coefficient B would have been more nearly in accordance with the results of direction of the ship in building, but for the masses of iron introduced in equipment, such as engines and boilers, armament, great funnel, &c. In fact, as the compass is only sixty-two feet from the stern, there

is a large excess of iron before that position compared with that abaft. We may reasonably assume the same of the B in the *Undaunted* before her iron masts were stepped.

It is now time to say something about these iron masts. The bowsprit and foremast are so far removed from the compasses that their effect may be regarded as zero. The mainmast also being at a distance of sixty-two feet from the standard compass, its red and blue poles must neutralize one another. At the steering-compasses a slight repulsion towards the stern may exist, but sufficiently small to be neglected.

When, however, we consider the position, of the mizzenmast, at a distance of only eight feet six inches from all compasses, we shall find that it has produced deviations of very decided amount and marked character; and therefore our attention may be confined to that mast alone.

This mizzenmast, which is eighty-two feet in length and twenty-four inches in diameter, was built at Chatham of the "best-best" iron, half an inch thick, the plates overlapping making it one inch thick at its thickest parts, and for the purposes of this discussion may be considered a hollow cylinder. The effects of iron in that form have been already treated on mathematically by the late Mr. Archibald Smith, F.R.S., in the Phil. Trans. Roy. Soc.

Whilst building, the mast lay in a horizontal position, the direction N. 43° W. and S. 43° E., heel towards the northward, which was a favorable position for that end of the mast to receive a permanent quantity of red magnetism as the riveting was proceeding. When the mast was stepped in its nearly vertical position and subjected to the tremor caused by the rapid revolutions of the screw and engines, red magnetism would become more and more developed. To test to what extent this was accomplished the following experiments were made.

At fifteen feet from the heel on the upper deck, and at twelve inches from the mast, a small compass was carried round, the blue pole of which pointed invariably to the mast. On the poop, at $22\frac{1}{2}$ feet from the heel and twelve inches from the mast, the blue pole of the compass was attracted three points. At $9\frac{1}{4}$ feet above the poop, and approaching the center of the mast, there was no attraction; but the neutral zone was very limited in extent, as the blue magnetism began to make itself felt a few inches further up. This description of the mizzenmast shows that at eight feet six inches from all compasses there exists a vertical, hollow, cylindrical magnet, the effects of which are clearly demonstrated by the following coefficients (see table on following page).

According to the custom of Her Majesty's navy the ships were swung when ready for sea, to ascertain the deviations of the standard and steering-compasses. The vertical force, however, on board the *Newcastle* was not observed, as in wooden ships experience has shown it to be so little disturbed. To remedy this deficiency I must now invite attention to another wooden frigate, H. M. S. *Challenger*. When the *Challenger* was about to start on her present voyage from Sheerness, an extended series of observations for the horizontal and vertical forces on board was made, in order to prepare for the correction of the magnetic observations now being carried out in her at sea.

This vessel was built at Woolwich, head S. 16° W., and fitted out at Sheerness; and the coefficients obtained in her at two positions have been introduced to confirm and supplement those of the *Newcastle*, especially as she is of the same construction, although smaller, and has wooden masts.

The notation and methods of computation of these coefficients are those given in the Admiralty Manual of the Deviations of the Compass.

The standard compasses are all within three inches of twelve feet six inches above the upper deck, the steering-compasses three feet nine inches above that deck, and six feet apart.

An examination of the values given in the Table shows that about 8° have been added to the B of the *Undaunted's* standard, but the C remains practically unaltered. This is evidently the effect of the red pole of the mast repelling the red pole of the compass towards the bow, and thus conspiring with the other iron of the ship to produce a large + B. Both the mast and compass being in the

TABLE OF COEFFICIENTS COMPUTED FROM DEVIATION TABLES OBSERVED AT SHEERNESS.

Name of Ship and Compass.	A.	B.	C.	D.	E.	Amount	Force.	Starboard Angle.	λ.	μ.	χ.
	° ′	° ′	° ′	° ′	° ′	°		°			° ′
Stand-ard. Newcastle,* 13, X, 74	−0 9	+7 6	−2 16	+0 18	−0 2	7¼	.128	342			
Challenger, 6, XII, 72...	−0 1	+6 28	+0 16	+0 23	−0 5	6¼	.113	2	1.003	.951	−0 7
Undaunted, 29, III, 75...	−0 14	+15 12	+2 53	+0 50	−0 2	15½	.269	10½	1.004	.831	−0 23
Starb'rd steering Newcastle, 13, X, 74	−0 57	+10 18	+0 23	+0 9	+0 59	10¼	.179	2			
Challenger,* 6, XII, 72...	+0 8	+6 7	+0 36	+0 16	−0 8	6¼	.108	5	1.006	.840	−0 24
Undaunted, 29, III, 75...	−3 8	+26 58	+18 18	+0 42	+0 11	33	.555	34	1.005	.724	−0 39
Port steering Newcastle, 13, X, 74	−1 46	+10 25	−10 2	+0 32	+1 5	14¼	.251	316			
Challenger,* 6, XII, 72..	+0 8	+6 7	+0 36	+0 16	−0 8	6¼	.108	5	1.006	.840	−0 24
Undaunted, 29, III, 75...	−1 4	+25 52	−13 26	+0 53	−0 41	20	.495	332	1.010	.716	−0 41

* The position of this compass is in the center line of the ship and the same height above deck as the steering-compasses; both of the latter may therefore be compared with it.

same fore-and-aft line, the C cannot be altered, and depends for its amount and sign on the diagonal riders before referred to. There is nothing unusual in the values of A, D, E, except that the *Undaunted's* D ranks among the largest observed in wooden vessels.

The λ (or the ratio of the mean horizontal force on board to that on shore, Earth=1.0) is at all the compasses a fraction above unity. This probably proceeds from the fact, already recorded, that the iron in these ships is in detached masses instead of its direction passing continuously through the compasses like iron beams, which invariably reduce λ below unity.

The μ (or the ratio of the mean vertical force on board to that on shore, Earth=1.0) in the *Challenger* shows how the red poles of the diagonal riders act in producing an upward force; but had the riders been joined at the keelson, it is almost certain that the μ would have been nearer unity at the expense of λ—a more desirable result, for this reason: experience has shown that λ may be reduced moderately below unity with no appreciable effect on the working of the compasses, whereas μ, upon which the heeling-error so much depends, should in wooden ships be as near unity as possible, heeling-error being troublesome to all navigators, and an insidious source of danger to the inexperienced.

In the *Undaunted* the μ at all compasses is evidently much reduced by the vertical component of the force produced by the red pole of the iron mast, which pole is very strong at a distance of sixteen feet, and at an angle of 35° from the vertical line passing through the standard compass.

The coefficient χ, or heeling-error which in these ships is to leeward, and practically dependent alone upon the value of μ (λ being so near unity and D so small), of course becomes greater in the *Undaunted* than in the two other ships.

So far all the coefficients at the standard compasses, and λ, μ, and χ at all compasses, have been examined; there remain therefore the A, B, C, D, E of the steering-compasses to be considered. For this purpose there is sufficient evidence in the two sister ships, which are strictly comparable.

The compasses are necessarily placed out of the central line of the ships, and diagonally to the mast under discussion; therefore, as shown by the figures in the Table, a transverse component is introduced. In effect the iron mast has increased the B of the *Undaunted's* steering-compasses by about 16°. To the + C of her starboard steering-compass about 11° have been added, and at the port steering a large —C of 13½° shows the transverse component of the mast's force more strongly than at the starboard; but the 2½° in excess are probably due to some other cause not accounted for by the observations made.

The A for these compasses is large in both ships; this does not, however, appear to proceed from magnetic causes, but rather from mechanical error in placing the binnacles. D and E show the results usual in wooden ships, except the D in the *Undaunted*, which is slightly increased.

Having thus, I think, defined the effects of the iron mizzenmast of the *Undaunted* on her compasses, it remains now to show what was the most desirable way of meeting them, and what was actually done in that direction.

The most certain cure of the evil would have been to remove all the compasses further away from the mast, as far as magnetic reasons are concerned; but this would have entailed serious alterations in the arrangements of the ship which the occasion by no means warranted.

The standard compass might have been raised to a level with the neutral zone of the mast, but this at the expense of increasing vibration in the card from greater length of pedestal.

The steering-compasses being in the most suitable position for the use of the helmsman, and there being the standard compass as a means of comparison and obtaining the correct course, no change of position was necessary. The three compasses were therefore corrected by magnets, the semicircular deviation being reduced to the same amount as in the *Newcastle*. It was not thought desirable to correct the whole of the semicircular deviation, as the mast, when the ship should make large changes of latitude, would probably add to the changing part of that deviation observed in this class of ships.

CONCLUSIONS.

The effects of iron masts are these:

1. They produce semicircular deviation, and the objectionable addition to that deviation known as heeling-error.

2. That these effects need not always be avoided, as in certain cases they may be made useful in experienced hands; for example, the principal mast in this discussion, might, in an iron ship built head north, be used to correct the —B of the standard compass, and oppose the downward pull of the ship's vertical force.

3. That the quadrantal deviation is slightly increased, and the mean directive force remains undisturbed.

4. Lastly, it is suggested that, as the magnetic condition of a mast may be easily ascertained by carrying a compass round it at stated distances and parts, the mast may be utilized or avoided as convenient. A similar examination of the mast in different latitudes would enable an observer to eliminate the effects of transient induced magnetism from the subpermanent. The amount of deviation proceeding from these causes is known for several classes of ships; but what part iron masts supply is yet a subject for inqniry.

SANITARY WORKS ABROAD.

From "The Building News."

A TRANSLATION of a report presented by a Commission appointed by the Minister of Public Works, to investigate the causes of the pollution of the Seine in the neighborhood of Paris, has been published by Mr. Robert Manning, M. Inst. C.E. It deals with the sources of the pollution of that river, and proposes measures for its remedy. As its proposals are of special interest to the sanitary authorities of all large towns, we may here give a *résumé* of them. The

Commission appointed in 1874, was composed of members of the Department of Public Works, and the Prefects of the Seine and the Police, and its report recounts the various measures that have been undertaken since 1869, the conferences held between the municipal authorities of Paris and the engineers of the navigation. The results of these conferences were submitted to the Council General des Ponts et Chaussées, and the opinion of the Council was adopted. The general conclusion pointed to the dredging of the river at certain points where the discharges of two intersecting sewers occurred at Clichy and St. Denis, and the development of experiments at Gennevilliers, for the purification of the sewage by irrigation. The report of the Commission first treats of the examination of the pollution of the Seine, near Paris, and the causes; and secondly, of the measures proposed for the purification. The outward appearances presented between Clichy and Rueil were of the most alarming kind. Below the bridge of Asnières, at the great intercepting sewer of Clichy, the river was a blackish current, exhibiting all the traces of foul contamination. This discharge from the sewer extends across the river in a parabolic curve. Organic *debris* of all sorts were seen floating, and this filth accumulated along the banks; shoals of organic matter were formed, some portion of which subsiding in the bed of the river, and fermenting, gave out at certain periods of the year large bubbles of gas, which burst at the surface of the river. From the isles of Clichy to that of St. Denis, this polluted stream of foam and scum dominates, destroying vegetation and too poisonous for fish. Manufacturing refuse increases the pollution. At St. Denis, below the Suspension Bridge, another interception sewer discharges its fetid contents, rendering the river black and viscid. Below Marley the two branches of the river unite, the water is less polluted, and at Meulan all visible signs of pollution disappear. Chemical examination confirm these superficial appearances. Organic nitrogen reaches its maximum at the Clichy sewer, while below St. Ouen there is a sensible diminution. Thus between Clichy and St. Denis the polluted branch of the river is quite unfit for domestic use, the fermentable elements are great, and the dissolved oxygen is almost *nil.* At Meulan organic nitrogen is greatly decreased. The causes of the pollution are next discussed. The outlets of Clichy and St. Denis discharge into the Seine a daily quantity of 260,000 cubic meters, or about three cubic meters per second, and about 771 kilometers (nearly five miles) of sewers are at present formed. The velocity of the river near Paris is very low—hence the sewage is thrown into a pool of stagnant water favoring decomposition. The second part of the report is devoted to the remedies proposed. Dredging of the solid detritus is insisted upon as one measure. It appears that 150,000 tons of solid matter is discharged during the year, and this subsiding creates shoals and banks of fermenting matter. Purification by chemical processes is considered insufficient and costly, especially the sulphate of alumina process, which only effects a mechanical clarification, two-thirds of the nitrogen remaining in the effluent water. Dr. Frankland's analysis of different re-agents tried shows that they only extract from the sewage water thirty-seven per cent. of the organic nitrogen, and the process above named leaves an enormous deposit behind in the basin. These facts have led the Commission to look upon chemical purification as abortive, and past experience shows the expense to be not less than one franc for every 100 cubic meters treated. Under such circumstances purification by the combined action of the soil and vegetation is proposed as the only solution. For this purpose the permeable soil of Gennevilliers was selected for irrigation, and the work was commenced in June, 1869. The sewage is raised by centrifugal pumps without valves (the engines being 150 horse-power) to a height of about eleven meters, into cast-iron pipes, which reach the plain of Gennevilliers. A conduit of masonry on side of departmental sewer, 1.60 meters high by 0.90 wide at commencement, is built between the gate of La Chapelle and the bridge of St. Ouen, and the inclination is sufficient to convey by gravity alone all the sewage from this side of Paris. The St. Ouen conduit can discharge the same quantity, or 44,000 cubic meters, per day. The sew-

age water from both sources unite on the embankment of Asnières and Gennevilliers, and the distribution is affected by furrows and ridges. The plain of Gennevilliers is an immense filter of alluvium, varying from seven to ten meters in depth; below this the infiltrated waters lie, forming a vast sheet, which has been found perfectly free from deposit of organic matter. The experiments are conclusive, and show that luxuriant vegetation is produced by the irrigation, and that the waters which return to the rivers are harmless. It has been shown that the matter in suspension is retained by the upper bed, and the organic azotic matter is absorbed by vegetation or oxydised by the subsoil, which retains its porous property. The Commission state that the whole sewage of Paris or 100 million cubic meters per annum can be disposed of on 2,000 hectares (about 5,000 acres) in the peninsula of Gennevilliers. An irrigation canal, extending to the Forest of St. Germain, is also proposed to take half the sewage, and next year it is thought the Seine will be largely purified.

A description of works in progress at Berlin for the sewerage of that city, and for the application of the sewage to irrigation, shows a miserable state of sanitary science a few years ago in Germany. Speaking of the two capitals, Vienna and Berlin, the former has just completed a water supply from the springs of Semmring at a considerable elevation above the city, by which the unwholesome wells are discarded, and Berlin has at last undertaken the far more urgent requirement of drainage, which she desires shall place her on a level with London and Paris. The city is comparatively modern, owing its prosperity to Frederick I. Before the revocation of the Edict of Nantes the population was only 20,000; now it is about a million. It is built on a sandy plain on the banks of the Spree, and has a total area of 6,250 hectares. The old town is on the right bank, and is composed of factories and stores; the new town, on the left bank, with its central boulevard of lime and chesnut trees, is characterised by more of the luxurious architecture of Paris, in which, however, a strong touch of Greek purism is evident. Like Paris and London, however, the city has been sanitarily neglected, and is only now awakening to a sense of its position. Its streets, badly paved, are rendered more dangerous by the open trenches which act as sewers, and discharge into the nearest arm of the Spree the house drainage. These are crossed by stone flags or planks. Rain water from the roofs and the house water from the kitchens flow on the surface, and the latrines empty into covered cesspools. Such a state of things existed when M. Hobrecht undertook the sanitary reconstruction of the capital. The principles adopted by him and his brother, the chief burgomaster, were circulation and the restitution of the sewage to the soil, besides an unlimited supply of pure water under pressure. Let us see what rules have been adopted for dwellings. A police ordinance of 1874 requires that where a main sewer exist every proprietor is compelled to connect his house with it by a drain 0.16 meters in diameter (about five inches). This drain serves for rain, household water, and water closets, but solid *débris* or refuse, cinders, &c., are forbidden to enter. The cesspits are abandoned for water-closets, and there are no longer open trenches in the streets, but these have curbed footways, with curved surfaces for the roadway, and with rectangular stone water tables. A plan of the drainage of each property is submitted according to another rule. As a measure of precaution the rain-water pipes are terminated by a syphon apparatus which retains any solid matter coming from the roof. The kitchen sink has a grating, and the house-drain is protected against the return of foul air from the sewer by a syphon and clack-valve, or flap, with a manhole for inspection. A water-rate is imposed by another order, and the city has purchased the works of an English company for the supply of water from the sands of the Spree. The cost is divided thus:—The works within the house are executed by owner, those in the street by the public authority. The decree gives a judicious power also to the authorities to construct the siphon, the valve, and the manhole, thus to ensure a proper junction of drain with sewer; and power is given to enter a house to see if the conditions have been complied with; a breach

of which is punishable by fine and imprisonment. Each house pays a certain proportion of the expenditure, including maintenance and interest on capital, according to a fixed scale. Ventilation of the houses is also undertaken, but water-supply and drainage are obligatory. As regards the streets the sewers are in the line of the open trenches, double and parallel lines corresponding with the footways being constructed, and these discharge into others running across at the intersections, which, in turn, discharge into the main sewers. There are thus three systems: the smallest are pipes, .22 meter in diameter, in double lines through the streets; the next, or branch drains, are stoneware pipes, .45 meter in diameter, or egg shaped brick sewers regulated at the two-thirds; and, lastly, the main intercepting sewers of brick, about 1.33 to two meters. Grated gullies or sumps are used for the streets, and manholes are placed at the junctions of the street in the lines of main and secondary sewers. Manholes, with perforated plates for ventilation, are also used. From the flatness of the city the sewerage is divided into districts, each having its own pumping engines. One of 360-horse power is in operation for Friederickstadt. The sewerage is received into a circular well twelve meters in diameter, divided by a strainer to prevent solids passing into the conduits. The sewerage is then discharged on an estate of 824 hectares, which is to be cultivated with vegetables, root-crops, &c.

This land is at Marienfelder, and is thirty meters above the pumping level. Like measures are being carried out on the left bank of the river, and another estate of equal area obtained for irrigation. The cost of the works are estimated at 40,000,000 of francs.

THE EFFECT OF MANGANESE IN BESSEMER METAL.

By AUGUST WENDEL.

Proceedings of American Institute of Mining Engineers.

It is a well-known fact to all Bessemer steel manufacturers using a blooming mill, that ingots show large cracks in the first few passes of the rolls, which, in the following ones, do not always roll up satisfactorily.

This deficiency in the quality of the product is generally called "redshortness," though, in the writer's opinion, mostly unjustly so. Different explanations for the said peculiarity are given by the leading authorities, every work selecting one element as a special scapegoat for the inferior quality of the ingot. The sulphur is generally first charged as being the principal cause of all mischief in this direction; then, after ascertaining that sulphur is not higher than the average, and sometimes lower in the very worst heats, silicon has to bear its share of abuse. How and why silicon should effect the working qualities of the metal, the writer could never precisely learn, but is convinced that the doctrine of its pernicious influence is an established one with many.

In cases where silicon failed to explain everything, resort was taken to calcium, aluminum, and some other known or unknown elements, without settling the difficulty; and lastly, when the skill of the chemist became exhausted, "practical men" came to the same conclusion, which many leading blast furnace managers had arrived at before, that analytical chemistry was good for nothing, but to disagreeably hamper the flight of their imagination. The trouble did not rest, however, entirely with the chemist, but with those who rather too hastily jumped at conclusions derived from his results.

Before making a few remarks on this subject, I would like to state that I do not propose to discuss anything about redshortness, legitimately so termed, but about the conditions necessary to allow the Bessemer ingots to stand the strain

of the two first grooves in the blooming mill, the absence of which quality the writer may term "want of body," no other appellation being known to him.

Every steel manufacturer knows that steel, rolling very badly in blooming, may be hammered to perfection, and, therefore, the mechanical test cannot be consistently taken as a criterion for its rolling qualities. Real redshortness, however, will show sooner or later in the material, no matter how worked. The conditions favorable to prevent this "want of body," are apparently due to the right proportion of carbon, silicon, and phosphorus to manganese, other conditions being equal; and the necessity of keeping this proportion within the proper limits, seems to increase with the increased size of ingots. From many analyses made, both of good and bad steel, I came to the invariable conclusion, that with steel having little phosphorus, in order to give certain satisfaction, the co-efficient $\frac{\text{Mn.}}{\text{C.} + \frac{1}{2}\text{Si.}}$ was larger than 0.8; and, with such as worked doubtfully or badly, it was smaller than this fraction, meaning, by the symbols, the respective percentages of the elements, carbon, silicon, and manganese, as estimated by the analyses of the steel.

This assumption may seem arbitrary, and the too small quantity of manganese in the product might be considered only indicative, that in the reaction there was not a sufficient surplus of manganese present to furnish a momentum for the more complete deoxydation of the Bessemer blow-holes; but, on the contrary, the writer claims that a certain surplus of manganese must be present as a constitutional element of metal intended for blooming. This latter assertion may easily be reconciled with the many observations of those who feared the bad influence of silicon in the quality. Those heats that contained silicon to a considerable degree, were generally blown rather short, and consequently contained not only silicon, but proportionately more carbon than they should have according to this co-efficient, especially if at the same time the spiegel had lost an unusual amount of manganese in melting.

Hot heats, that are liable to be blown too short, come mostly in this category, and this led to the opinion that the highly silicious irons were more likely to produce this want of body—a deficiency which may be easily remedied by blowing sufficiently, that is, removing both silicon and carbon as much as possible, before recarburization. This explains why steel from hot heats almost invariably rolls badly when blown too short, but I have seen a most excellent quality of steel from heats excessively hot.

A theory about the beneficial influence of the manganese in preventing the "want of body" may not be necessary, as the remarks in this paper are entirely empirical. But, I am inclined to assume that manganese combines with carbon and silicon in certain proportions in lieu of iron, thereby changing the constitution of the metal, although such a statement may seem very heterodox in view of the preponderant quantity of iron present.

The second and more important part of these considerations, is the influence of phosphorus on the want of body. It is a well-known fact, that phosphorus does not increase the redshortness of steel or wrought iron, and that, on the the contrary, many metallurgists claim that the bad effects of sulphur are counteracted or modified by the presence of phosphorus. But the writer is clearly convinced, that this dictum cannot be applied to Bessemer metal rolled in a blooming mill.

Some time ago, Bessemer steel came under the writer's observation, of which the analyses showed the following composition:

Carbon.....	0.28	0.29	0.30
Manganese...	0.907	0.837	0.925
Phosphorus..	0.524	0.498	0.513
Sulphur.....	0.088	0.086	0.084

I only give the analyses of three heats, as sufficient to represent the composition of others, whose working qualities were the same. This metal showed less sulphur than the average then manufactured; the quantity of manganese was more than sufficient to neutralize both carbon and silicon, and still the ingots crumbled up under the rolls, and most of them had to be taken from the tables in many pieces after a few passes. Both low and high heats were tried, but either

way it was impossible to roll the ingots without disintegrating them. This steel showed only a very slight reaction, if any, in the vessel on recarburization; and looked, when poured into the moulds, exactly like un-recarburized, or rather, un-manganized metal. The only explanation for this strange behavior, might be that the spiegel used on this occasion, contained little or no manganese. That this was not the case both the analyses of the spiegel, containing about eleven per cent., and of the steel, subsequently showed.

The percentage of phosphorus in this instance was excessive, but afterwards I was fortunate enough to observe a similar bad run of steel with phosphorus as low as 0.20 per cent. Now phosphorus by itself does not impart such peculiarities to iron as those described above, and the only way to escape from this dilemma was to take for granted a large affinity of phosphorus and manganese at the temperature of the molten metal, both combining to some kind of phosphide of manganese in the act of recarburization; so that manganese instead of combining with the oxygens of the bath, combines with the phosphorus present, partly or entirely, and so becomes rather paralyzed in its proper sphere. The fact of the manganese percentage being unusually high rather strengthens this opinion, inasmuch as the manganese, by simply combining with phosphorus, will not show any decrease of quantity otherwise produced by the oxydation of this metal. An explanation like the one given may be contrary to the traditional notions concerning the affinity of elements, but it must be doubted whether the affinities have been much studied in temperatures and under conditions such as those we are concerned in at present. Is it not just as unlikely that gas bubbles should be retained in a molten metal where such a high temperature ought to give them a somewhat considerable expansion? And still they stick to the great discomfiture of Bessemer men. It seems to be much less of an improbability that manganese should combine with phosphorus in preference to oxygen, which fact, if it be one, may become just as disagreeable to the manufacturer.

I purposely refrain from giving any formulae of polycarburets and polyphosphides, which, hypothetical as they always must be, would have to be made probable by synthetic experiments outside of the compass of this paper. Smaller quantities of phosphorus of course could not paralyze the deoxydizing influence of manganese, but will do so to a certain degree as observed by me.

In order to overcome the bad influence of phosphorus in the rolling of Bessemer ingots, I would suggest that the percentage of manganese in the steel should be four times as large as that of phosphorus, in addition to the manganese quantity required for the neutralization of carbon and silicon, according to the co-efficient given above. The proportions given by me may need modification, but they certainly do not yield a larger percentage of manganese than required, if the manufacturer desires to be safe. This would not exclude the possibility that some steel with smaller percentages of manganese may roll tolerably well. I need hardly say that steel made from manganiferous irons by blowing short and without recarburization does not come under these considerations.

As an illustration of my theory I must add a few remarks about the irregular working of different heats made from the same irons and blown with the same care. It must have puzzled every manufacturer to find that a very bad blow is sometimes made between two excellent ones. This led the writer first to the opinion that not the absolute quantities of one or more elements in the iron, but rather some relative proportions of elements, changeable in conversion, influence the working of the metal.

There are two kinds of bad heats which prominently present themselves in this connection. In the first place the bad rolling heat does not show any abnormal carbon percentage, it being the average, and still the ingots break badly at the rolls. In that case the manganese percentage is low, which is easily accounted for by an excessive loss of manganese in melting the spiegel.

The second kind shows a percentage of carbon much lower than the average, which is explained by the fact that the heat in question did not get the requisite

amount of spiegel by carelessness or otherwise. Now as the carbon in this case varies with the manganese percentage, the latter must be high enough to neutralize the carbon, but in most cases it is not high enough to counteract phosphorus. The steel, with some mixtures, will roll to perfection with low carbons. What mixtures will do it? Those low in phosphorus.

The moral from this is easily drawn. If you cannot reduce your phosphorus, take care to keep your manganese as high as possible.

Before attempting to utilize, for Bessemer works, irons with a higher percentage of phosphorus than has hitherto been allowed, it would be well to investigate whether the quantity of manganese necessary to insure the good rolling of the ingot does not impart too much brittleness to the product when cold; and, according to results obtained, the manganese must be kept to the required limits.

The statement of the Terre-Noire authorities, that one part of phosphorus imparts to the metal a hardness equal to two parts of carbon, seems to be rather preposterous. According to this statement, some iron rails would compare very favorably with those of steel in wear, and still they show more wear, excluding lamination.

Phosphorus cannot be substituted for carbon, but the manganese combines phosphorus and renders the metal hard and stiff, just as carbon would do. This is the reason why phosphorus steel with little carbon is hard, but it would be simply cold short with an insufficient quantity of manganese. In the first place the metal is a phosphor-manganese steel; in the second, a carbon-manganese steel, with phosphorus. Open hearth manufacturers have better opportunities to obtain a varying quantity of elements in their product than Bessemer people, who are somewhat hampered by being forced to introduce too large quantities of manganese, in order to give body to their ingot for reasons sufficiently explained; and therefore, from them we have to expect important developments in iron metallurgy.

In order not to get confused on the terms hardness, brittleness, coldshortness, etc., which are used promiscuously by many theorists, according to their several predilections, I will now conclude this paper, and leave it to the United States Test Commission to investigate how the varying relative proportion of elements influences the strength of the material.

HEALTHY HABITATIONS.

By Mr. W. EASSIE, C. E.

From "The Builder."

We are told upon the best authority that there occurs annually in this country upwards of 4½ millions of cases of preventible sickness, and that 125,000 persons are prematurely cut off every year from a neglect of sanitary precautions. We are accustomed to consider that the house is to blame for this desperate state of things, and the case is certainly a strong one. We dress in the morning, and unsuspectingly don linen washed, dried, and ironed in the home of a laundress, the inmates of whose non-disinfected household have been stricken down with fever. Or the contagious matter may have been imported in the woolen interstices of a coat shapen and sewn by an out-working tailor whose seat-board was within the length of a rose-tree from some one whom fever is fast hailing to the silent land. We then breakfast, and if we escape enteric poison in the milk-jug it is entirely owing to the cleanly surroundings of the farm or dairy. The meal over, the post may bring us some infection in a newspaper, not one newly radiant from the press, but fresh from a friend whose house is under a fever-cloud, as was the case the other day, when the virus of scarlatina

was conveyed from far Inverness to Exmouth. The Nemesis of uncleanness follows the innocent traveler, too, for "mine hostess of the inn" has perhaps permitted him to sleep in a bed last occupied by one who had just sickened or who had insufficiently recovered from some ailment. Even if the bed be without reproach, his slumber may not have given him corresponding relaxation, and draughts from the window or chimney may have induced a violent cold just when the greatest radiation from his skin prevailed, and he was powerless to avert it. Or the faint night breeze may be loaded with the invisible horrors of sewer-gas, which we all know very well is not an imaginary case.

Alas for the very poor, whom we shall have always with us, how do they suffer from domiciliary uncleanness! They risk the eating of cheap, unfit food, and the drinking of putrid water, we know; but they may also sleep upon beds made up of shredded rags which the dealers have collected from the marine stores and town dust-yards, innocent of cleansing or disinfection. Their wearing material is sometimes also just the shoddy made up of woolen rag flocks, from no one knows where, or they may have been purchased in the clothes-exchange of some rag-fair, and stored with germs only lacking an opportunity for mischief. A late outbreak of scarlatina in Hereford was traced to an old-clothes shop of this description. The furniture, also, of the poor classes is as likely as not purchased at an auction, the sale of which, fresh from an infected house, was not arrested by the health officer, as was a late sale at Sydenham. Nor do the poor suffer alone; they perforce communicate it to those around them. During the present year at Chippenham, the pew-cleaner bore infection into a family pew. The saddest case I know of occurred also this year at Leeds, where typhus was carried with some infected articles into a pawnbroker's house, and with fatal results. Sanitarians must aim at improving the dwellings of the poor first of all, and the hands of the health inspectors ought to be strengthened, so that they may not only seek out, but promptly remove the engendering evils. As fast as a crocodile's egg is discovered an ichneumon should be let loose upon it. The medical officer of health and his inspectors are here the masters of the situation, or rather should be, not the magistrate and his Admirables of the Blue. Perhaps, however, some day the police will get tired of so much hunting up of cases for the Board school, and will supplement a fair share of that by furnishing a list of sanitary delinquencies to the proper authorities.

The first chief consideration when about to erect a house is that of procuring a suitable site. In cities we have little choice except that of avoiding the neighborhood of rank nuisances, such as slaughter-houses or gas-works. But it would, perhaps, be better to have built there the town residence rather than upon the more aristocratic site, since the foundations would have, it may be, to be built in trenches dug out of soft core. The laboring man suffers exactly in the same way, with this enhancement of evil, that in his case the house may be built up for the most part of old materials sold with the site, bricks sodden with the impurities of a century, and put together with mortar manufactured out of filth-saturated plaster. If the history of the 129,000 houses which have been erected during the last ten years in London were accurately known, some desperate revelations might be expected, and a great deal of metropolitan sickness accounted for. We ought, as has been said, to have a due knowledge of the amount of population in each street of every city within the land, and thus be able to detect unhealthy areas by separating the cases of zymotic diseases from other seizures. By this means the cause of filth diseases might be rooted out. The late Dr. Ross pointed out a street in St. Giles's district, London, in which there was in the course of each year a death in every house. In the neighborhood of a square in the same district the mortality was only one in forty-one houses. Not density, and not overcrowding, however, caused the fatality in the street named, but defects of construction and arrangement in the houses, and, above all, dirt inconceivable.

I have heard it repeatedly remarked that the mansions of the good old times were invariably built upon exceptionally good spots, and with which no fault

could be found. This may be true of most abbeys and priories, the sites of which were chosen by conclaves of wise men, but is not true if predicted of many old mansions; since I have frequently seen these, though commanding the finest views, abandoned to the owl, and new residences built at some distance, because of the healthiness of the fresh site. If our forefathers erred, however, occasionally, we err very frequently indeed. I could point out houses, dwelt in by partricians of our own land, the subsoil of which is continually—in flood-time or dry harvest—charged with the water of adjacent streams or lakes, the water having actually to be pumped out of the cellars at stated times. Many modern mansions have I met too, which, had been erected as if in the bottom of a saucer of water-bearing rocks, and which are never dry.

When houses are built upon alluvial soil and the subsoil water lies close to the surface, the advent of malarious diseases may be regarded as a certainty. Paroxysmal fevers have also been traced to the digging up of the wide gravel walks in the gardens of houses unprovided with a subsoil drainage. A great deal has lately been said of the fevers due to the disturbance of the soil in Rome, and many experiments upon the ground-air have been made at home and upon the Continent. It is necessary that such experiments be made, for a medical man has lately related how, in Carlisle, he suffered for nine weeks from a fever due to the disturbance of the soil in the neighborhood for the purpose of leveling a building site and constructing a new road on the estate. The prevailing winds must also be taken into account, for where the house has been erected regardless of proximous fens or marshes, and there are many even in crowded England, the malarial factors are many and intense. And, apart from all this, houses are sometimes rendered unbearable through standing open-mouthed in the way of winds blown from dry sewage outfalls and supersaturated lands. I know a nobleman's house one wing of which is made most uncomfortable during certain winds by chemical works fully three miles distant. To a very serious degree, indeed, do dwellers in manufacturing cities and towns suffer when the noisome works are crowded in amongst the dwellings. These manufacturing vapors, during northerly and easterly winds especially, increase the local death-rates enormously. In Glasgow, when such vapors are condensed in fogs, the poorer districts, well opened to their influence, have suffered a mortality of over sixty-five per 1,000, as against nineteen to thirty-six per 1,000 in the better parts of the city at the same time. If there stands a sufficient reason for the weeding out of too closely congregated public-houses on the score of morality, a much greater necessity obtains for the better isolation of these unhealthy factories. And just as intramural burying-grounds have been banished to the suburbs, so should these atmosphere-poisoning laboratories be gradually moved on to the outlying districts, even should a workman's railway follow each of them.

It is customary with us to condemn the erection of a residence upon clayed soils, and to praise gravelly ones, but the choice is not always a happy one. True, drift gravels may be free from sinister imputations, and so may deep permeable gravels and deep sandy soils, such as our Bagshots; for there the chance is that the many escapying wastes from our dwellings may filter harmlessly away. But shallow gravels, and gravels of mere river origin, if these rest upon non-absorbent rocks, are to be suspected, inasmuch as the wastes which sink through them would anon reach the surface again. There is no natural surface-drainage possible in such cases, and the adjective well-poisoning is also here well applied. Now, upon a clay soil—and cholera flies a clay soil—it has been remarked, all this evil can be avoided; the foundations can be built upon concrete, and even the whole basement, whilst the wastes can be drawn without fear of soakages. As a rule, all house sites should be drained just as fields are drained, and below even the concreting.

The greatest care should therefore be exercised in making a proper choice of a site. If the district be very damp and marshy, the influence of miasmas cannot, I think be averted by any amount of gum-tree or sunflower planting, however much moisture these may dispose of, and Dutch experiments on clean-

water ditches to the contrary notwithstanding. They cannot be reckoned to counteract the evils of a subsoil continuously fed with impure liquids. It has been said that it is in the power of floriculture to conquer a whole district from deadly malaria by covering it with aromatic vegetation, and the inspired writer may have had this in his mind when he spoke of the desert blossoming as a rose; but powerful as is the peculiarity of certain flowering plants to produce ozone, on exposure to the sun's rays, they could have but little effect upon the surroundings of a house which can only be drained in the subsoil upon which it immediately rests.

A word or two as to the prospect and aspect of a house, and the necessity of this has been carefully elaborated by Professor Kerr. The prospect may be chosen with the view to making the most of the scenery. As regards aspect, the north is best allotted to the dining-room, as the twilight lasts longest there, and the staircases are also best when arranged upon this side of the house, being always cool. For the larder and dairy this aspect is unexceptionally good. The bedrooms will be found most comfortable when facing the north-east, as they get a pleasant morning sun, and are correspondingly cool at night. The east is suitable for the breakfast-room, morning, and library, but not for the drawing-room, because of the east winds and lack of afternoon sunshine. In the south-east may be placed the reception and best rooms, and for a sick room this aspect is not to be surpassed for fitness. The south is unsuited for the dining-room windows, except there be a good verandah; and as for the south-west, it is the worse aspect of all, and unpleasantly hot for bed-rooms. Neither is the west to be purposely chosen for bedrooms, or even for a dining-room; it is suitable, however, for the smoking-room and for one side of the conservatory. The north-west is suitable for an evening-room if fitted with good blinds. To conclude, the east aspect is dry, but sometimes subject to bitter winds, which planting may obviate. The south-east is also dry and the winds mild, whilst the south is eminently sultry. The worst aspects are the south-west, with its frequent rains and boisterous winds; the west, with its rain and undue warmth; and the north, with its prevailing coldness.

It may be said that this care as to the aspect is mere sumptuousness, but not so. Even in the case of a laborer's cottage in the country, when there was the whole welkin to choose from, how often do we see a senseless choice made,—just as we see a senseless choice made with villas when aspect has been ruthlessly sacrificed for prospect's sake. The bed-rooms of the farm laborer's family may look out on the north or south-west, the kitchen faces the west, the dairy the south, and the privy, dust-midden, and piggery dung-pit are all clustered together where the sunbeams most do congregate, instead of the north. I have no practical remark to make upon this part of my theme, except to lament that intending investors do not oftener have recourse to models before they transmute their money into bricks and mortar. This precaution would cost little more than one per cent. on the outlay, and would save much heartburning. It is only what every good engineer does before he builds a bridge or constructs the simplest piece of machinery.

But to approach the house closer, ceasing, however, the alternate harpings upon rich and poor residences, and choosing a building of moderate pretensions as a representative erection. As we near it we diagnose immediately and safely as to its healthy condition. If a damp one, it carries intemperance upon its face; its walls are dun-colored in patches, due to dampness in the walls, a dampness which can be traced up outside at times to the first floor. The wet yards speak gushingly of water hidden below the pavement, and which cannot run its allotted course to the nearest brook. Once inside, we notice the damp basement floors which not the coal-wasting kitchen fire can recover to normal dryness; and in the more neglected rooms of the same floor it would seem as if they were intended for the production of newts and frogs. This is no overcharged picture, and is as bad many times when there is no cellar accommodation. The ensteepment of the house is moreover traceable elsewhere than in the ground-floor, in the cupboards of which, by the way, mouldiness grows upon the boots almost in a night's time; for in the

library upstairs a mildew prevails, making limpid the rare leather bindings; and the sense of mustiness is ever present, even in the bedrooms. It is as if a premium had been held out to shiverings, rheums, and agues. Only last week I visited an ancestral hall in Lincolnshire, and found out just such a state of things in a new wing which had been built about a year. The painters of a noted West-end firm were busy coating the walls with oil paint, and nearly as fast as the coats were put on the water rose upon the walls and bulged out the paint into blisters, resembling those generated by a severe burn, and needing, in similar fashion, only the prick of a knife to liberate the water.

The state of things in this mansion was simply due to building the foundations without concrete underneath, and without any damp-course to intercept the rising wet. Had the site been drained, even, it would have been less of a blunder. Dampness in houses is often traceable to having laid the stone, tile, or brick paving upon the damp earth, one consequence of which may be that the floor will perhaps be lifted up out of its place by underside growths. Under every circumstance a bed of concrete should sublie all paving. Another cause of humidity in the house is due to the banking up of damp earth against the walls, and the non-provision of an area wall. The latter, like virtue, is indispensable, and the contractor who provides it when the designer of the house has omitted to specify it is worthy of the Order of the Pope's Silver Rose, if he has more than the "Golden" one. I would say to the builder—Put it in, even should you never get paid for it; for, depend upon it, if you do not, the residence will always be cited against you as a badly built one, and your balance due will be escheated, which may cause you a sweating sickness in the bank parlor. I may also here add, that the moistness due to the non-placement of a damp-proof course can alone be remedied by cutting out the wall and inserting one above ground-level line. No damp-proof paints can long withstand the enemy behind, which, when it ceases its legitimate march through the wall, only begins to crumble away at the wall material behind. True, it can be hidden from the eye by boarded linings, but truce is only for a time.

I have often been called to a residence where a dank and unpleasant smell was prevalent, and traced it to nothing but rot. I do not allude to the wet rot which seizes wood alternately wet and dry, as between wind and weather of a fence-post, but the dry rot which is due to the placing of unseasoned wood, or, indeed, any wood in close contiguity to the surface mould and the gases evolved in its decay, and in situations where there are no ventilating air-bricks, and consequently no change of air. Floor joists which have been long surrounded by dead air will weigh light as a feather when taken up, all due to fungus growths and the like. The worst of it, too, is, that by a catalytic action the decaying wood infects the sound, and the mischief never ceases until that whole level of floors is destroyed. If, on inspection, the attack has been found a moderate one, and the space between the joists and the ground sufficient, the infected places may be cut out and the space ventilated. A pipe may also be laid underneath the fire-grate for a time, to insure thorough drying. But if the joists rest on the bare ground, the only remedy is to take them up, dig out the earth, laying down some concrete if necessary, and refix fresh and seasoned timbers. I would not depend even upon sulphate of copper or chlorine. Many architects specify the joists to be treated with various solutions, under pressure or otherwise; but it is really not necessary if good ventilation amid joists be provided. With greater reason should we seek to preserve our wood-carvings from the ravages of those three species of beetles which require plenty of light and open air, and would seem to look upon a rich chasing as does a gourmand upon a sumptuous repast. One wonders, nevertheless, how our fathers escaped these pests, and why we do not find the powdering rot or the shell-lined burrows in the time-honored timbers of our many abbeys. I carefully examined an Egyptian coffin the other day at Dresden, and it showed decay of no kind. My own impression is that we build far too quickly, and out of undesiccated materials.

Pass we to the walls of the house. Bad walls may be constructed of too-

porous materials, which will allow the beating wet to pass through them. Here the advantage of hollow walls is manifest, down the interior space of which the moisture may trickle and be carried away. It has been suggested that walls should be built of impermeable materials, to prevent the intrusion of water; and at one ironworks alone in this country some 120,000 bricks formed out of blast furnace slag, are turned out weekly. But in a house built in Bavaria with this very material, it was found that, although dry at first, it proved unbearably damp in the end; the reason being that the vapors given off in cooking, washing, and breathing simply condensed upon the inner surface and remained there. The truth is a wall must breathe; and even with the doors, windows, and registers shut, a sensible supply of air should pass in and out of the room through the wall substance. This is supplying fresh air without draught, and as was intended by Nature. For this reason also it is wrong to paint the walls either inside or outside, to cover them with varnished papers, or, in fact, to do aught but distemper them with water-color which cannot close up the pores. For so surely as we do prove treasonable to Nature in this matter, so certainly shall we suffer. In halls and in corridors where ventilation is constant, and where one merely passes and repasses, we may indulge to the long length of our purses in marbles, casings, tiled dados, and oil-painted spaces; but in our living-rooms and dormitories let us beware of such innovations.

The walls of a room, may, however, be properly enough built and yet act prejudicially, owing to the papering bestowed upon them. I need say nothing, however, of the arsenical papers and the poisonous flock papers, for householders are now mainly alert to the mischief which they work, and are even demanding that Government paternal should forbid their importation or manufacture amongst us. That arsenic is sometimes poisonous, even when present upon smooth substances, was proved the other day at Bonn, where a professor and two students were seized with violent headaches, and where the mischief was traced to the green shade over the lamp, which was colored by the poison, and which the heat of the lamp had set free. In like manner the dust falling from the poisonous wall-papers is dangerous when breathed by the inmates of a room. Such dust is even conveyed to other rooms by our senseless habit of dusting with dry cloths upon the floor. Nor does the evil of paper-hanging end here; for coat upon coat of paper and paste, size and paper, may sometimes be found on the walls of a house just got up for an incoming tenant. I have seen seven different paperings, embodying apparently every taste under the sun, taken from the walls of a single room, and the difference to the occupant afterwards was something wonderful.

Ventilation and heating I treat as kindred subjects, and as dependent upon each other as are the boiler and firebox of the engine upon the coal and water of the tender. I have examined in many countries some hundreds of patents, and seen generally, I believe, all that has been most lauded in the way of ventilating houses, and I have found that the best systems have always been the simplest. First of all, decide whether you will adopt the common firegrate or the ventilating fireplace. If you adopt the ordinary firegrate in the living-rooms,—and choose you the old Rumford pattern,—supply it with air from without, and it will then cease to draw cold air from the passages and chill your feet as you sit by the fire. Then provide an inlet of cold air, broken up by passing it through a grating, such inlet to be from the floor line as high as one can conveniently reach. As for the outlet, if you have a separate foul air-flue running up alongside of the chimney-flue, insert an Arnott's or a Boyle's mica-valved ventilator into that just below the cornice; and if you have no separate shaft, then insert the ventilator into the smoke-flue. I would further recommend a shallow ventilator over the head of each door, the whole width of the door, and with the means of closing it in winter. In summer, when all these are open, the effect is congratulatory. But be sure that the kitchen is well shut off, or well ventilated of itself, with separate inlets and a strongly withdrawing foul air-shaft.

In the case of bedrooms, where common grates are to be used, I would equip the doors with the same ventilating

panel overhead. But I would furthermore raise the lower sash of the window three inches, filling up the gap below by a piece of wood stretched across the opening. Provide, also, the means of lowering the top sash. The lower sash being lifted up, a never-ceasing air-current from outside is directed between the meeting bars and driven upwards towards the ceiling, being, moreover, sensibly warmed in its passage. The outlets will be found at the registers of the grates or at the valves in the chimney-breasts. Mr. R. Rawlinson, who kindly showed me, at his own residence, windows fitted up upon this system, has expressed himself to the effect that this plan of Dr. Bird's is the best possible arrangement. The living and bed rooms thus ventilated, there remains the staircase, which should be provided with an outlet. Mr. Rawlinson lifts up the flat ceiling-light a little; and where there is none I would make an opening into the outer air at the highest point, with a protection-box to prevent an inward current.

If the owner make choice of ventilating grates behind or around which a chamber is formed, in which air from without is warmed and allowed to enter the room at about mantel-piece level, and if the architect has built separate foul-air flues alongside the smoke-flues, I would still provide the valvular ventilators in the chimney-breast, because I have seen them act beneficially. But if no such separate flues exist, these should not be inserted in the smoke-flue, as might be done with impunity with a common fire. The behavior of the hot air, as it issues from the warm-air chamber, is to mount to the ceiling, adown the wall, dispersing itself pretty equally throughout the room, and then across the floor to the fire. But although this is so, I would nevertheless introduce some inlets for fresh air during the summer, and, moreover retain the power of withdrawing the respired air by means of the foul-air flue in the chimney-breast.

When building a house I would always provide the panel over the door, and separate air-flues to supply the fires with air for combustion. Between the smoke-flues I also invariably provide a foul-air shaft, terminating a few inches above the ridge on the sheltered side of the chimney-stack. In the case of a cottage, one such foul-air flue will serve several rooms, but in larger mansions I always make a separate air-withdrawing flue to each room. In the reception-rooms and other large rooms I cause on each wall, during the process of building the walls, a four-inch shaft to be built from the ground-line to the eaves, and these can be made to act as inlets or outlets according to the weather. In the depth of winter, also, they are readily utilized for gas calorigens.

I need not, I think, describe the whole-house system of ventilation, although I warmly approve of it; because it must be studied in detail. Here a single inlet of warm or cold air is provided for the whole house, and also one common abstraction shaft as an outlet, with controllable valves and other requisites. It has proved a great success where it has been tried by Drs. Drysdale and Hayward, and if properly attended to will change the air in every room of the house every twenty minutes. I am afraid, however, that the system would be too costly for general use.

I have only one word more to say on this part of the subject, and that is that, whenever possible, a vestibule should be constructed in the hall, and the air warmed for the hall use, and for the use of all the passages. The advantage of the ventilating panels over the doors will then also be felt. But the stove or calorigen should be fed with a tube-conveyed stream of pure air to be warmed within it, for delivery into the room. If hot-water pipes or coils are used, bring in all the same the stream of cold air to the under side of the pipes or coils, and save the churning and burning of the air over and over again. Moreover, if there be a coil-case, see that it runs on castors, and enables the servant to dust the pipes,—burnt dust being very offensive.

Ventilation should be so perfect as to permit even of the withdrawal of any lighting gas which may have escaped, or at least for a sufficient dilution of the gas to prevent the recurrence of such disasters as the late one at Arbroath, where three people perished by suffocation. The results of gas poisoning have been carefully noted, and the reports of

the necropsies given by Dr. Lockie, of Sunderland, in which city a youth of eighteen years was poisoned, and by Dr. Sneddon, of Beith, where a man, aged thirty, and a cat perished together. Within the past two years leaks from gas pipes have also caused explosions, which resulted in the loss of three lives at Southgate and two at North Durham, and London has had lately to lament the loss of Dr. Foster by a similar calamity. Serious explosions have also occurred at Sheffield, Wirksworth, Rochester, Ashbourn, and doubtless at an endless number of unreported places. Sometimes gas has escaped into the house from leaks in the main outside, and gas will creep along underground for an astonishing distance. It has been traced for thirty feet, and even across a roadway on one occasion. The only cure for this evil is to compel the companies to insert stop-valves in their mains, so that the flow of gas from a fractured pipe can be prevented pending its restoration.

But I would recommend more than this, and nothing less than the compulsory testing by the gas companies of the house-pipes before their commodity was allowed to pass through them. And I would insist upon the pipes being tested every time the reading of the meter was taken. With our system of working, the gas companies are independent of the leakage going on in the house-pipes.

Now, in America, before the gas companies will make the connection with the meter, they satisfy themselves that the pipes are intact. The contrivance used for testing is a force-pump of simple construction, and connected by a tube with the only one of the burners which has not been plugged up. If, after forcing the air into the pipes, the mercury rises in the gauge and remains steadily at the one height after the stop-cock has been shut off, the pipes are sound. But I have often seen the mercury dance up the pipe and disappear when the pumping ceases, in which case either there is a leak at the joint or a split at the weld, or may be there is a plug left out behind the papering, as happened to be the case the other day, or peradventure something has happened to the composition piping. It would not matter very much certainly whether the gasfitter were bound to test the pipes before the gas company laid on the gas, or whether the gas company are compelled to test the gas before they connected to the main, so that the pipes were tested. I have seen here in London the most disgraceful jobs in the way of gasfitting which nothing but a systematic testing would have discovered. Another improvement which should be encouraged is the use of a gas-regulator. The best one I know can be seen in use at Judkin's, of Fleet Street.

As we perambulate through our ideal mansion, the next thing we would likely take notice of would be the water-pipes and the cisterns. In no house, whether the water supplied be hard or soft, should the water for culinary or drinking purposes be conveyed in leaden pipes. I will not insult my hearers by recapitulating the reasons for this precaution. Of late years the lead-encased block-tin pipe has been found to obviate very many of the evils complained of in lead pipes, and it will always have good work to perform for the community. But a still better pipe is used in America, and steps are just now being taken to introduce it into this country. I refer to the glass-lined water and gas pipe, in which the water comes into contact with glass only, and in which there can be neither oxydation nor corrosion. The interior being smooth also, there is less friction, and consequently the flow of water can be carried upwards with less pressure. Fortunately, too, the resisting power is very much greater than lead, and the cost is very little more than lead pipe. Those who have used it in America say that they would rather pay for this pipe than have any other fixed for them free of charge. It is constructed of an iron exterior casing, and between that and the glass is a compressible plastic substance, which is both a non-conductor of heat and cold. It is certainly a great advance upon everything that has yet appeared as a water or gas conveying medium, and deserves universal patronage.

One thing is quite certain, and that is, leaden cisterns should be abolished altogether, or confined simply to the supply cistern over the closets. I do not think either that galvanized iron cisterns are fit for the storage of water, inasmuch as zinc is a coarse metal easily oxydized.

Poisoning by the oxide of zinc deposited in the cheaply galvanized iron cisterns and along the zinced pipes have been somewhat frequent. Thus, too, we have been obliged to discontinue the use of zinc-lined kitchen utensils. Paper collars also, when they were covered with zinc white, caused eruptions around the neck whenever the perspiration dissolved the zinc coating. I believe the best and handiest materials for cisterns will be found to be slate, enameled inside. I always specify them, if used for drinking-water, in order that the least dust within will be discoverable at a glance.

When a house is supplied with well water only, it is wise to periodically analyze it. Seventy-five per cent. of waters sent from the country has proved on analysis to be unfit for use. I have a client at the present time residing in London who has fled a magnificent country seat, simply because not a well on the house premises can be found to yield good water. When sickness first seized the establishment, the drainage was suspected, and certainly some serious evils were laid bare and remedied, but nevertheless the unhealthiness continued, and at last the water proved to be the delinquent; and the strangest part of the matter was, that the water which had been considered best on the estate, and which had not long ago been brought into the house at great cost by a neighboring plumber, proved to be the very worst sample of the lot. Wells are more often than otherwise poisoned by the infiltration of sewage matter, but not unfrequently are they made unwholesome by the introduction of lead suction-pipe. When a well has been found impure, and it becomes incumbent to sink another, I make a trial of the most likely spot with the aid of a tube well, and if the discovered water proves to be good on analysis, I sink a well there. Several of these tube wells are now, however, driven at intervals apart, and, united by longitudinal pipes, are brought to one spot where a pump is fixed. This is often found to be cheaper and even better than sinking a well.

Many residences in the country are entirely short of water, taken either direct from the river, or raised from the water-bearing rocks. There is, therefore, nothing remaining for them but the utilization of the rain-water. But in such cases I carefully exclude the supply from lead flats, and use them in the soil-drains for flushing. In every case, however, where rain-water is used for drinking and cooking purposes, it should be well filtered. Sometimes I use a simple filter of one chamber, the water rising through sand and gravel, and in a general way this is sufficient. But cases do occur when it becomes necessary to interpose a depositing-tank previously to the water finding its way into the cistern, and when one must also use a more compound filtering media, as, for instance, chalk and charcoal, and shingle or sand. And when the sole supply of the house is derived from the rain-water collection tank, especial care should be taken to keep the gutters and downspouts in a cleanly state. It is perfectly astounding what impurities will collect there in a few months, what a load of fecal matter, and what dead atomies of winged life. And not only should an overflow be provided for the tank, but a drain from the bottom, fitted with a plug and spindle, so as to facilitate cleaning. These drains should not, however, lead into the soil-drains. For the rest, a large ventilating pipe should be led up out of the tank to the open air.

I am surprised, considering how long the cylinder system of hot-water heating has been known, to see how persistently our best engineering firms continue in the use of the huge boiler at the back of the fire, and all its liabilities to explosion and other drawbacks. So thorough a case has been made out against the system, that I am sure every one is acquainted with its demerits. Indeed, the very method of its supply—from the often filthy small supply cistern in the corner, or in the dark cupboard, or even in the wall, is enough to prove that there is too much of the hole-and-corner business in it to guarantee perfect cleanliness. On one occasion, in Wimpole Street, London, I saw the small cistern mud thick with the remains of dead beetles and cockroaches, nor would the defilement have been discovered had not the decoction in time discolored the water, and induced a search.

In the cylinder system of hot water supply—and I never in any case recommend any other for washing up or for

bath water—I use the Dyer patent. The cold water is at the top of the house, and the hot water cylinder near the fire. There is no need of a circulating hot water cistern upstairs, neither of any small-feed cisterns downstairs. The cold water from the upstairs cistern enters near the bottom of the cylinder, and the boiler of the apparatus is of the smallest possible size. Should frost set in, and no water flow from the upper cold water cistern to the cylinder, so as to force the hot water up, there will simply be a stop to the supply of the hot water for a time, but as the cylinder will be nearly full of water all the time, the small boiler will always be kept charged, and remain so until the frost surrenders. It is impossible to empty the cylinder from any of the taps, although it is in the power of the master or mistress to open a sluice-cock and empty it when it requires to be cleansed out. It may occur, of course, that a small boiler in connection with the nursery or still-room fires would prove a great boon, and there is no objection to these. But there is to the large coffin-sized boiler at the back of the kitchen and scullery fires, it being a perpetual menace to the lives of the household, and worse than the sword of Damocles. With the cylinder system it is also possible to heat a few coils for warming the rooms and passages; but the coils should be galvanized if the water is wanted free from discoloration.

People are now so tired of being lectured upon drainage, of the danger of laying pipes under houses, of using bad drain pipes, and not truly turned ones, like Stanford's; of the propriety of a good fall for the pipes; or good joints free from stuck-up shirt collars of cement inside; and have so often been told how a coating of tar round the outside of the pipe will prevent the entry of roots at any joint, that they smile simply, and hazard an opinion as to their entire acquaintance with all that could possibly be said upon the subject. This boast would, however, be a fallacious one, for with an engineer in good practice nearly ever week brings him a fresh fact to startle him as to what evils may be silently working, mole-like, underground, and sapping the health of too trustful ones. Too much can scarcely ever be said regarding the danger of permitting old cesspools and brick drains to remain inside a house, and of the propriety of even searching for them, if the house be an old one, the very moment that the first smell is manifest, or when the first rat crosses the Rubicon. I look upon the sewer rat as really a beneficent animal, sent by Providence to warn us of the possibility of sewer-gas eruptions. He is to cleanliness in the drain what the *Cimix lectularius* is to cleanliness in the bed, a sort of moral *gendarme* flying in the face of danger even to bid you be wise in time. And just as I would search for old cesspools and brick drains, and abolish them, so would I get rid of all the filthy places in and about the stableyard, the garden, and even the kitchen offices, and replace them with earth contrivances of automatic action.

I never look upon the word trap in a book, or see one, but I am reminded of the deceptive character of the article. We must have traps, I know very well, but we do not require many save in the streets, at the gullies, or just before the house-drain enters the main-drain, the sewer, or the cesspool. We try to cut off all connection with the sealed drain by the insertion of an article not much larger than an old-fashioned watch, and with a water seal hardly thicker than its silver back, and believe we can resist the influences of gases generated in about, say, ten miles of sewer, and seeking an entrance into the rarefied atmosphere of the house. The idea is monstrous, and ought to have needed no Dr. Fergus to have laboriously ridiculed it. The best trap is the syphon-trap, when it is a syphon, but I have seen so very many imperfect syphons, both in earthenware and lead, that I would almost insist upon having a worshipful order of syphons, in order to obtain a hall-mark upon them, and so be certain that they really trapped. I took out of a mansion the other day in Lincolnshire a leaden bend supposed to trap, and which a plumber had not long put in, and I characterize its condition and beauty of shape sufficiently when I say that it is now in the museum of the establishment, and duly labeled.

I am almost forgetting our imaginary house, but we will see the state of our waste deliveries. Does the cistern over-

flow deliver into the soil-pipe?—cut it. Does the bath waste so deliver?—cut that off. So do the sinks of the housemaids', butler's, and housekeeper's rooms so deliver, cut them off also. Let nothing go into the drain direct, and disconnect in every direction. But what is disconnection? Well, if you take the cistern waste-pipe out of the soil-pipe, or out of the rainwater-pipe connected with the drain, and allow the cistern waste to deliver in the face of day upon the roof, or the pavement below, that is disconnection. If you find that the waste-pipe of the lead safe under the watercloset goes into the soil-pipe, and thousands do, or into the D trap, and if you make a simple hole in the wall, and put the lead waste-pipe through it, you have disconnected such lead closet safe. In like manner, if the kitchen or scullery sink runs direct into the drain, trapped or otherwise, and if you lead the waste out through the wall, and cause it to deliver in the open air over a grease-trap, or just under a ventilating grid, that kitchen waste has been disconnected. Formerly it was deemed sufficient to interpose a small body of water between the inside of the house and the drain, but now, in place of this, we interpose an open-air space between the trapping water in the drain and the ends of the wastes outside the house. The rule is now to allow a current of fresh air freely to travel from the disconnecting tanks up the soil-pipes, and so out at the roof, the constant action being maintained by the adoption of a foul-air withdrawing cowl. Instead of the house-drains containing pent-up gases and foul air, they are now made into highways for fresh air, and the difference in favor of health is self-evident. No matter what pattern of closet be used,—hopper, pan, or valve, the latter with or without D traps, if this disconnection be carried out with the soil-pipe,—and Mr. Field was, I believe, the first to venture upon so bold a course,—if there be a momentary exposure of the wastes, from that moment of exposure the house is safe. Between the foot or two of exposure and the larger drain, the sewer or the cesspool, can be put a syphon, and nothing will force that, or if gas does so on any one occasion, it will simply rise out of the disconnecting chamber, up through the grating, and be harmlessly dispersed in the open air.

Lord Byron bade his readers of "Childe Harold" farewell on the banks of the ocean, and the idea was in keeping with the high sustained character of the poem. In like manner I will bid my hearers adieu at the edge of the dust-bin, that microcosm of good and macrocosm of evil. How many fevers have been traced to that sarcophagus-looking box, to that mausoleum-looking tomb under the area steps, or in the vault of the close back yard? I think the only cure is for the authorities to forbid the mixing together of the kitchen refuse,—and this may mean anything, from the lungs of a hare to the stalk of a lettuce,—and the dust proper, that is, the ashes and house sweepings. I would also forbid the placing of the dust-bin below the floor level. Your time will not permit me to say more at present, but I have indicated, I hope, some of the chief reasons why houses prove unhealthy, and with your leave will revert to others on some future occasion.

FORCE.*

From "English Mechanic."

HAVING shown that perhaps the most essential thing in science is accuracy or definiteness, the learned professor proceeded to consider various totally inconsistent modes in which the word "force" has been used. But, before going fully into this subject, he said it was necessary to premise some observations with reference to our modes of becoming acquainted with external nature and its laws. It is absolutely necessary, he remarked, to keep well in mind the all-important principle that nothing can be learned as to the physical world except by observation and experiment, or by mathematical de-

* An abstract of the lecture on Force, delivered by Professor Tait, before the members of the British Association, at the Crystal Palace, Glasgow.

ductions from data so obtained—that man had been left entirely to himself as regards the acquirement of physical knowledge, but has been gifted with various senses without which he could not even know that the physical world exists, and with reason to enable him to control and understand their indications. To sight without reason, the universe appears to be filled with light, except, of course, in places surrounded by opaque bodies. Reason, controlling the indications of sense, shows us that the sensation of light is our own property, and that what we understand by brightness does not exist outside our minds. It shows us, also, that the sensation of color is purely subjective. To hearing without reason, the air of a busy town seems to be filled with sounds. Reason, interpreting the indications of sense, tells us that if we could see the particles of air we should observe amongst them simply a comparatively slow agitation of the nature of alternative pressure and dilatation. A blow from a stick or a stone produces pain and a bruise; but the motion of a stick or a stone before it reaches the body, is as different from the sensation produced by the blow, as is the alternate compression and dilatation of the air from the sensation of sound. Thus the direct indications of sense are in general utterly misleading, and most especially as to the relative temperatures of the different bodies. The lecturer most carefully warned his audience to distinguish between heat and the mere sensation of warmth, just as they distinguished between the motion of a cudgel and the pain produced by the blow. The one is the thing to be measured, the other is only the more or less imperfect reading or indication given by the instrument with which we attempt to measure it, so that when our muscular sense impresses on us the notion that we are exerting force, as in pushing or pulling, we ought to be very cautious in forming judgment as to what is really going on, and we ought to demand much further evidence before admitting the objective reality of force. Whether there is such a thing as force or not, there can be no doubt that it is a convenient term, provided it be employed in one definite sense, and one only. The sense in which Newton uses the word "force," and therefore the sense in which we must continually use it if we desire to avoid intellectual confusion, will appear clearly from a brief consideration of his simple statement of the laws of motion. After quoting these laws, the lecturer said that any change whether in the direction or in the rate of motion of a body, is attributed to force. Thus, a stone let fall, moves quicker and quicker, and we say that force—namely, the weight of the stone, or the earth's attraction for it—is continually acting so as to increase the rate of motion. If the stone be thrown upwards, the rate of its motion continually diminishes, and we say that the same force is continually acting so as to produce this diminution of speed. So far, no one, probably, feels the least difficulty, but we have got only half of the notion on this point which Newton's first law affords. We see the moon revolving about the earth, and the earth and other planets revolving about the sun, approximately at least, in circles. Why is this? Their directions of motion are constantly changing; but to produce this change of direction force is required just as much as to produce change of speed.

The old notion was that a centripetal force was required to balance the so-called centrifugal force, it being imagined that a body moving in a circle had a tendency to fly outwards from the center. Newton's simple law exposed in full the absurdity of this. If a body is to be made to move in a curved line, instead of its natural straight path, you must apply force to compel it to do so. In fact, inertia means not revolutionary activity, but dogged perseverance; and just as we must apply force in the direction of motion to change the rate of motion, so must we apply force perpendicular to the direction of motion to change that direction. After defining momentum as the product of a mass moving into the velocity with which it moves, the lecturer proceeded to show that Newton's second law enables us to define the unit of force as that which, whatever be its source, produces a unit of momentum in the unit of time. Employing British units, a unit of force is that which, in one second, gives to one pound of matter a velocity of one foot per second. It is to be carefully noticed that a pound of mat-

ter is a certain mass or quantity of matter. When we buy a pound of tea we buy a quantity of the matter called tea equal in mass to the standard pound of matter. The idea of weight does not enter primarily into the process—in fact, the use of the ordinary balance depends upon one clause of Newton's law of gravitation, which tells us that the weights of bodies are equal if their mass is equal. The weight of a pound of matter varies from place to place on the earth's surface. It depends upon the attracting as well as upon the attracted body. The mass of a body is its own property; the weight of a body is the force which produces in it in one second a velocity which in this latitude is about thirty-two feet per second, so that in Glasgow the weight of a pound, which we take as our standard unit of mass, is rather more than thirty-three units of force, or, what comes to the same thing, the British unit of force is about the former weight of a penny letter—half an ounce. The lecturer went on to show the monstrosity of confounding force with momentum, and to make clear to his audience that he had not overstated the atrocity of such a comparison, he showed that, by changing the unit of time, amounts of force and momentum which were before equal might be made to bear any desired proportion to one another. The two things were therefore shown to be of quite dissimilar nature, and such as could not be lawfully equated to one another under any circumstances whatever. Newton's first two laws, he continued, leave absolutely no doubt as to the only definite and correct meaning of the word "force." It is obviously to be applied to any pull, push, pressure, tension, attraction, or repulsion, whether applied by a stick, or a string, a chain, or a girder, or by means of an invisible medium whose existence is made certain by the phenomena of light and of radiant heat. Thus we see how to get rid of two gratuitous absurdities—so-called centrifugal force and the so-called accelerating force.

We must now proceed to exterminate what is called living force. Cormorant and Blunderbore have been disposed of, but a more dangerous giant remains—the more dangerous because he is a reality and not a phantom. Whatever force may be, there is no such thing as centrifugal force, and accelerating force is not a physical idea at all; but that which is generally denoted by the term living force, as it has absolutely no right to be called force, is something as real as matter itself. To understand its nature we must have recourse to the "Principia." The lecturer proceeded to show that Newton, in all but one particular, had anticipated the modern statement of the conservation of energy. Energy was used by Newton in a sense of work, not force, as is too often represented, but force exerted through a space. No one having the slightest ideas of accuracy could possibly confound two things so different as force and energy, any more than he would attempt to measure the height of a mountain in acres, or the arable land of an estate in cubic miles. Newton's words, put into modern language, but without changing the meaning, stand thus:—"If the action of an agent be measured by the product of its force into its velocity, and if, similarly, the reaction of a resistance be measured by the velocities of its several parts into their several forces, whether these arise from friction, cohesion, weight, or acceleration, action and reaction, in all combinations of machines, will be equal and opposite." The actions and reactions which are here stated to be equal and opposite are no longer simple forces, but the products of forces into their velocities. They are what are now called "rates of doing work," the increase per second of a very tangible and real something, for the measurement of which rate Watt introduced the practical unit of a horse power, or the rate at which an agent works when it lifts 33,000 pounds one foot high per minute against the earth's attraction. Thus it appears that force is a mere name, and that the product of the force into the displacement of this point of application is that which has an objective existence.

Modern science shows us that force is merely a convenient term employed for the present, very usefully, to shorten what would otherwise be cumbrous expressions, but it is not to be regarded as a thing any more than the bank-rate of interest is to be looked upon as a sum of money, or the birth-rate of a country is to be looked upon as the actual group of

children born in the year. The lecturer then passed on to consider the various forms of energy and their mutual relation, and how force was exemplified as in each case the rate of transformation of energy per unit of length between two bodies or systems. After defining potential and kinetic energy, he proceeded to show that Rumford and Davy, at the very end of last century, showed conclusively that the materiality of heat could not be maintained, and thus gave the means of completing Newton's statement, which, still further extended and generalized, now stands as one of the most massive pillars of the fast rising temple of science known as the Law of the Conservation of Energy. Dr. Tait went on to say:—The conception of kinetic energy is a very simple one, at least where visible motion alone is involved. And from motion of visible masses to those motions of the particles of bodies whose energies we call heat is by no means a very difficult mental transition. Mark, however, that heat is not the mere motion, but the energy of these motions (a very different thing), for heat and kinetic energy in general are no more "modes of motion" than potential energy of every kind (including that of unfired gunpowder) is a "mode of rest." In fact a "mode of motion" is, if the word motion be used in its ordinary sense, purely kinematical, not physical, and if motion be used in Newton's sense, it refers to momentum, not to energy. The conception of potential energy, however, is not by any means so easy or direct; in fact, the apparently direct testimony of our muscular sense to the existence of force makes it at first much easier for us to conceive of force than of potential energy. Why two masses of matter possess potential energy when separated—in virtue of which they are conveniently said to attract one another—is still one of the most obscure problems in physics. I have not now time to enter on a discussion of the very inglorious idea of the ultramundane corpuscles, the outcome of the life-work of Le Sage, and the only even apparently hopeful attempt which has yet been made to explain the mechanism of gravitation. The most singular thing about it is that if it be true it will probably lead us to regard all kinds of energy as ultimately kinetic. And a singularly quasi-metaphysical argument may be raised on this point of which I can only give the barest outline. The natural convertibility of kinetic and potential energy shows that relations of equality (though not necessarily of identity) can exist between the two; and thus that their proper expressions involve the same fundamental units and in the same way. Thus, as we have already seen that kinetic energy involves the unit of mass and the square of the linear unit directly, together with the square of the time unit inversely, the same must be the case with potential energy. And it seems very singular that potential energy should thus essentially involve the unit of time, if it do not ultimately depend in some way on energy of motion.

One of the worst blunders of the much lauded early paper of Mayer, upon which an attempt was made to found for him the full claim to the original discovery of the conservation of energy, was reproduced in an intensified form by Dr. Tyndall, in his discourse on what he erroneously called "force." As that discourse involves essentially a good deal of the particular kind of error, to the exposure of which my present lecture has been devoted, I may fitly finish with a brief examination of some of the most inaccurate of the statements there made. Here they are from the *Philosophical Magazine* for July, 1862, where they form part of a paper which has already been effectively commented on, but mainly from an historical point of view, by Sir William Thomson and myself; "The absolute amount of work done depends solely upon two things—first of all on the quantity of matter that is lifted, and secondly on the height to which it is lifted. If you call the quantity or mass of matter M, and the height through which it is lifted N, then the product of M into N, or M N, expresses the amount of work done." Now the words "quantity or mass of matter," are perfectly definite, and cannot possibly involve anything beyond a numerical multiple of the unit of mass. The height to which the mass is raised is, of course, a simple numerical multiple of the work of length. The product of these two quantities thus defined by Dr. Tyndall as "work done"—*i.e.*, the product of a

mass into a length—is not as yet recognized in physics at all. We have seen that work or energy essentially involves two additional factors—viz., a numerical multiple of the unit of length directly, and of the square of the time-unit inversely. One of the extraordinary mistakes involved in such a statement as that which I have just quoted will be obvious to every one of you when I point out that the statement involves no mention of gravitation whatever, so that, according to such writers, the work done in lifting a load in no way depends upon the earth's attraction, but would be exactly the same whatever were the mass of the earth. Perhaps nothing so rich, and yet so sad, as this has been published as science since a scientific author, supposed to be the late Lord Brougham, undertook, at short notice, to write one of the earlier treatises of the "Library of Useful Knowledge." All but a very few copies were recalled, but in those which were not destroyed we are told that a porter carries a load on his shoulders rather than in his hands because it is thus lifted at least twice as high above the earth, and gravity diminishes as the square of the distance from the attracting body increases! When I find men who make these blunders in science, where at least in the elements accuracy is not only indispensable but easily attainable—when I find these men unsettling by vague and altogether unscientific speculations the cherished beliefs of their fellow-men, on matters of unutterably greater moment, I conceive that I am morally bound, in season and out of season, to take every possible opportunity of showing the true value at which to estimate their scientific authority. Shall "these be thy gods, O Israel?" To conclude, in defence of accuracy, which is the *sine qua non* of all science, we must be "zealous, as it were, even to slaying;" and that, as all the power of the *Times* will not compel us to put a "y" instead of an "e" into the word chemist, so neither will the bad example of Germany and France, though recommended to us with all the authority which may be attributed to an ex-president of this Association, succeed in inducing us to attach two or more perfectly distinct and incompatible scientific meanings to that useful little word "force," which Newton has once and forever defined for us, with his transcendent clearness of conception.

Dr. Andrews expressed his concurrence with the remarks of Professor Tait as to the importance of exactness in the use of language. They all knew, however, that language was marvelously flexible, and unless words were multiplied far beyond the number to be found in any language there must be various significations. One word might be used correctly by Newton and at the same time it might not be always employed in the same sense by others; and he believed there were few then present except the learned gentlemen there who would undertake to write an essay, even after hearing Professor Tait lecture, without falling into some serious error.

Professor Stokes, in moving a vote of thanks to Professor Tait, observed that when he first heard of the subject the lecturer had chosen he felt somewhat puzzled. He felt that it was one very suitable for an assembly of professed mathematicians or physicists, but he had great difficulty in conceiving in what manner it could be rendered interesting or generally intelligible to a mixed audience. He owned that he should have been sorry himself to have been obliged to lecture before such an audience on such a subject. But the lively genius of his friend Professor Tait had thrown a mantle over the dry subject with which he had dealt, and had caused the lecture to be listened to with a silent attention that showed the interest it had aroused—a silence only broken by the marks of approbation with which certain passages were received. He could not help feeling, in reference to the latter part of the lecture, that the context of a man's words might often throw a light upon his meaning, but this was a matter that had been alluded to by the President, and he would not pursue it further.

THE Richmond Select Vestry have voted £2,339 odd for the purchase of an old brewery, the site of a proposed artesian well, the water from which it is intended to pump up to a reservoir in Richmond Park, about to be constructed with the approval of Her Majesty's Office of Works.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Abstract of the Address of THOMAS ANDREWS, M.D., LL.D., F.R.S., President.

From "The Engineer."

Six and thirty years have passed over since the British Association for the Advancement of Science held its tenth meeting in this city (Glasgow), and twenty-one years have elapsed since it last assembled here. The representatives of two great Scottish families presided on these occasions; and those who had the advantage of hearing the address of the Duke of Argyll in 1855 will recall the gratification they enjoyed while listening to the thoughtful sentiments which reflected a mind of rare cultivation and varied acquirements. On the present occasion I have undertaken, not without anxiety, the duty of filling an office at first accepted by one whom Scotland and the Association would alike have rejoiced to see in this chair, not only as a tribute to his own scientific services, but also as recognizing in him the worthy representative of that long line of able men who have upheld the pre-eminent position attained by the Scottish schools of medicine in the middle of the last century, when the mantle of Boerhaave fell upon Munro and Cullen.

The task of addressing this Association, always a difficult one, is not rendered easier when the meeting is held in a place which presents the rare combination of being at once an ancient seat of learning and a great center of modern industry. Time will not permit me to refer to the distinguished men who in early days have left here their mark behind them; and I regret it the more, as there is a growing tendency to exaggerate the value of later discoveries, and to underrate the achievements of those who have lived before us. Confining our attention to a period reaching back to little more than a century, it appears that during that time three new sciences arose, at least as far as any science can be said to have a distinct origin, in this city of Glasgow—experimental chemistry, political economy, and mechanical engineering. It is now conceded that Black laid the foundation of modern chemistry; and no one has ever disputed the claims of Adam Smith and of Watt to having not only founded, but largely built up, the two great branches of knowledge with which their names will always be inseparably connected. It was here that Dr. Thomas Thomson established the first school of practical chemistry in Great Britain, and that Sir W. Hooker gave to the chair of botany a European celebrity; it was here that Graham discovered the law of gaseous diffusion and the properties of polybasic acids; it was here that Stenhouse and Anderson, Rankine and J. Thomson, made some of their finest discoveries; and it was here that Sir William Thomson conducted his physito-mathematical investigations, and invented those exquisite instruments, valuable alike for ocean telegraphy and for scientific use, which are among the finest trophies of recent science. Nor must the names of Tennant, Mackintosh, Neilson, Walter Crum, Young, and Napier be omitted, who, with many others in this place, have made large and valuable additions to practical science.

The safe return of the Challenger, after an absence of three and a half years, is a subject of general congratulation. Our knowledge of the varied forms of animal life, and of the remains of animal life which occur, it is now known, over large tracts of the bed of the ocean, is chiefly derived from the observations made in the Challenger and in the previous deep-sea expeditions which were organized by Sir Wyville Thomson and Dr. Carpenter. The physical observations, and especially those on the temperature of the ocean, which were systematically conducted throughout the whole voyage of the Challenger, have already supplied valuable data for the resolution of the great question of ocean currents. Upon this question, which has been discussed with singular ability, but under different aspects, by Dr. Carpenter and Mr. Croll, I cannot attempt

here to enter; nor will I venture to forestall, by any crude analysis of my own, the narrative which Sir William Thomson has kindly undertaken to give of his own achievements and of those of his staff during their long scientific cruise. Another expedition, which has more than fulfilled the expectations of the public, is Lieutenant Cameron's remarkable journey across the continent of Africa. It is by such enterprizes, happily conceived and ably executed, that we may hope at no distant day to see the Arab slave dealer replaced by the legitimate trader, and the depressed populations of Africa gradually brought within the pale of civilized life.

From the North Polar Expedition no intelligence has been received; nor can we expect for some time to hear whether it has succeeded in the crowning object of Arctic enterprise. In the opinion of many, the results, scientific, or other, to be gained by a full survey of the Arctic regions can never be of such value as to justify the risk and cost which must be incurred. But it is not by cold calculations of this kind that great discoveries are made or great enterprizes achieved. There is an inward and irrepressible impulse—in individuals called a spirit of adventure, in nations a spirit of enterprise—which impels mankind forward to explore every part of the world we inhabit, however inhospitable or difficult of access; and if the country claiming the foremost place among maritime nations shrink from an undertaking because it is perilous, other countries will not be slow to seize the post of honor. If it be possible for man to reach the poles of the earth, whether north or south, the feat must sooner or later be accomplished; and the country of the successful adventurers will be thereby raised in the scale of nations.

The discovery of Huggins that some of the fixed stars are moving towards and others receding from our system, has been fully confirmed by a careful series of observations lately made by Mr. Christie in the Observatory of Greenwich. Mr. Huggins has not been able to discover any indications of a proper motion in the nebulæ but this may arise from the motion of translation being less than the method would discover. Few achievements in the history of science are more wonderful than the measurement of the proper motions of the fixed stars, from observing the relative position of two delicate lines of light in the field of the telescope. The observation of the American astronomer Young, that bright lines corresponding to the ordinary lines of Fraunhofer reversed, may be seen in the lower strata of the solar atmosphere for a few moments during a total eclipse, has been confirmed by Mr. Stone, on the occasion of the total eclipse of the sun which occurred some time ago in South Africa. In the outer corona, or higher regions of the sun's atmosphere, a single green line only was seen, the same which had been already described by Young.

I can here refer only in general terms to the observations of Roscoe and Schuster on the absorption-bands of potassium and sodium, and to the investigations of Lockyer on the absorptive powers of metallic and metalloidal vapors at different temperatures. From the vapors of calcium the latter has obtained two wholly distinct spectra, one belonging to a low, and the other to a high, temperature. Mr. Lockyer is also engaged on a new and greatly extended map of the solar spectrum.

Spectrum analysis has lately led to the discovery of a new metal, gallium; the fifth whose presence has been first indicated by that powerful agent. This discovery is due to M. Lecoq de Boisbaudran,, already favorably known by a work on the application of the spectroscope to chemical analysis. Our knowledge of aërolites has of late years been greatly increased; and I cannot occupy a few moments of your time more usefully than by briefly referring to the subject. So recently as 1860 the most remarkable meteoric fall on record, not even excepting that of L'Aigle, occurred near the village of New Concord, in Ohio. On a day when no thunder-clouds were visible, loud sounds were heard resembling claps of thunder, followed by a large fall of meteoric stones, some of which were distinctly seen to strike the earth. One stone, above fifty pounds in weight, buried itself to the depth of two feet in the ground, and when dug out was found to be still warm. In 1872 another remarkable meteorite, at first seen as brilliant as a star, with a luminous train, burst

near Orvinio, in Italy, and six fragments of it were afterwards collected.

Isolated masses of metallic iron, or rather of an alloy of iron and nickel, similar in composition and properties to the iron usually diffused in meteoric stones, have been found here and there on the surface of the earth; some of large size, as one described by Pallas, which weighed about two-thirds of a ton. Of the meteoric origin of these masses of iron there is little room for doubt, although no record exists of their fall. Sir Edward Sabine, whose life has been devoted with rare fidelity to the pursuit of science, and to whose untiring efforts this Association largely owes the position it now occupies, was the pioneer of the newer discoveries in meteoric science. Eight and fifty years ago he visited with Captain Ross the northern shores of Baffin's Bay, and made the interesting discovery that the knife blades used by the Esquimaux in the vicinity of the Arctic highlands were formed of meteoric iron. This observation was afterwards fully confirmed; and scattered blocks of meteoric iron have been found from time to time around Baffin's Bay. But it was not till 1870 that the meteoric treasures of Baffin's Bay were truly discovered. In that year Nordenskiöld found, at a part of the shore difficult to approach even in moderate weather, enormons blocks of meteoric iron, the largest weighing nearly twenty tons, imbedded in a ridge of basaltic rock, The interest of this observation is greatly enhanced by the circumstances that these masses of meteoric iron, like the basalt with which they are associated, do not belong to the present geological epoch, but must have fallen long before the actual arrangement of land and sea existed,—during, in short, the middle Tertiary, or Miocene period of Lyell.

Weather telegraphy, or the reporting by telegraph the state of the weather at selected stations to a central office, so that notice of the probable approach of storms may be given to the seaports, has become in this country an organized system; and considering the little progress meteorology has made as a science, the results may be considered to be on the whole satisfactory. Of the warnings issued of late years, four out of five were justified by the occurrence of gales or strong winds. Few storms occurred for which no warnings have been given; but, unfortunately, among these were some of the heaviest gales of the period. The stations from which daily reports are sent to the meteorological office in London, embrace the whole cost of Western Europe, including the Shetland Isles. It appears that atmospheric disturbances seldom cross the Atlantic without being greatly altered in character, and that the origin of most of our storms lies eastward of the longitude of Newfoundland. As regards the velocity of the wind, the cup-anemometer of Dr. Robinson has fully realized the expectations of its discoverer; and the venerable astronomer of Armagh has been engaged during the past summer, with all the ardor of youth, in a course of laborious experiments to determine the constants of his instrument. From seven year's observations at the Observatory of Armagh, he has found that the mean velocity of the wind is greatest in the S. S. W. octant, and least in the opposite one, and that the amount of wind attains a maximum in January, after which it steadily decreases, with one slight exception, till July, augmenting again till the end of the year.

Passiug to the subject of electricity, it is with pleasure that I have to announce the failure of a recent attempt to deprive Oerstedt of his great discovery. It is gratifying thus to find high reputations vindicated, and names which all men love to honor transmitted with undiminished luster to posterity. At a former meeting of this Association, remarkable for an unusual attendance of distinguished foreigners, the central figure was Oerstedt. On that occasion Sir John Herschel in glowing language compared Oerstedt's discovery to the blessed dew of heaven, which only the master-mind could draw down, but which it was for others to turn to account, and use for the fertilization of the earth. To Franklin, Volta, Coulomb, Oerstedt, Ampère, Faraday, Seebeck, and Ohm are due the fundamental discoveries of modern electricity—a science whose applications in Davy's hands led to grander results than alchemist ever dreamed of, and in the hands of others—among whom Wheatstone, Morse, and Thomson occupy the foremost place—to the marvels of the

electric telegraph. When we proceed from the actual phenomena of electricity to the molecular conditions upon which those phenomena depend, we are confronted with questions as recondite as any with which the physicist has had to deal, but towards the solution of which the researches of Faraday have contributed the most precious materials. The theory of electrical and magnetic action occupied formerly the powerful minds of Poisson, Green, and Gauss; and among the living it will surely not be invidious to cite the names of Weber, Helmholtz, Thomas, and Clerk Maxwell. The work of the latter on electricity is an original essay worthy in every way of the great reputation and of the clear and far-seeing intellect of its author. Among recent investigations I must refer to Professor Tait's discovery of consecutive neutral points in certain thermo-electrical junctions, for which he was lately awarded the Keith prize. This discovery has been the result of an elaborate investigation of the properties of thermo-electrical currents, and is specially interesting in reference to the theory of dynamical electricity. Nor can I omit to mention the very interesting and original experiments of Dr. Kerr on the dielectric state, from which it appears that when electricity of high tension is passed through dielectrics, a change of molecular arrangement occurs, slowly in the case of solids, quickly in the case of liquids, and that the lines of electric force are in some cases lines of compression, in other cases lines of extension.

Of the many discoveries in physical science due to Sir William Grove, the earliest and not the least important is the battery which bears his name, and is to this day the most powerful of all voltaic arrangements; but with a Grove's battery of fifty or even 100 cells in vigorous action, the spark will not pass through an appreciable distance of cold air. By using a very large number of cells, carefully insulated and charged with water, Mr. Gassiot succeeded in obtaining a short spark through air; and lately De la Rue and Müller have constructed a large chloride of silver battery giving freely sparks through cold air, which, when a column of pure water is interposed in the circuit, accurately resemble those of the common electrical machine. The length of the spark increasing nearly as the square of the number of cells, it has been calculated that with 100,000 elements of this battery the discharge should take place through a distance of no less than eight feet in air.

In the solar beam we have an agent of surpassing power, the investigation of whose properties by Newton forms an epoch in the history of experimental science scarcely less important than the discovery of the law of gravitation in the history of physical astronomy. Three actions characterize the solar beam, or, indeed, more or less that of any luminous body—the heating, the physiological, and the chemical. In the ordinary solar beam we can modify the relative amount of these actions by passing it through different media, and we can thus have luminous rays with little heating or little chemical action. In the case of the moon's rays it required the highest skill on the part of Lord Rosse, even with all the resources of the observatory at Parsonstown, to investigate their heating properties, and to show that the surface of our satellite facing the earth passes, during every lunation, through a greater range of temperature than the difference between the freezing and boiling points of water. But if, instead of taking an ordinary ray of light, we analyse it as Newton did by the prism, and isolate a very fine line of the spectrum—theoretically a line of infinite tenuity—that is to say, if we take a ray of definite refrangibility, it will be found impossible by screens or otherwise to alter its properties. It was his clear perception of the truth of this principle that led Stokes to his great discovery of the cause of epipolic dispersion, in which he showed that many bodies had the power of absorbing dark rays of high refrangibility and of emitting them as luminous rays of lower refrangibility—of absorbing, in short, darkness, and of emitting it as light. It is not, indeed, an easy matter in all cases to say whether a given effect is due to the action of heat or light; and the question which of these forces is the efficient agent in causing the motion of the tiny discs in Crooke's radiometer has given rise to a good deal of discussion. The answer to this ques-

tion involves the same principles as those by which the image traced on the daguerreotype plate, or the decomposition of carbonic acid by the leaves of plants, is referred to the action of light and not of heat; and applying these principles to the experiments made with the radiometer, the weight of evidence appears to be in favor of the view that the repulsion of the blackened surfaces of the discs is due to a thermal reaction occurring in a highly rarefied medium. I have myself had the pleasure of witnessing many of Mr. Crooke's experiments, and I cannot sufficiently express my admiration of the care and skill with which he has pursued this investigation. The remarkable repulsions he has observed in the most perfect vacua hitherto attained are interesting, not only as having led to the construction of a beautiful instrument, but as being likely, when the subject is fully investigated, to give valuable data for the theory of molecular actions.

Switzerland, sent, some years ago, as its representative to this country, the celebrated De la Rive, whose scientific life formed lately the subject of an eloquent *éloge* from the pen of M. Dumas. On this occasion we have to welcome, in General Menabrea, a distinguished representative both of the kingdom of Italy and of Italian science. His great work on the determination of the pressures and tensions in an elastic system is of too abstruse a character to be discussed in this address; but the principle it contains may be briefly stated in the following words:—"When any elastic system places itself in equilibrium under the action of external forces, the work developed by the internal forces is a minimum." General Menabrea has, however, other and special claims upon us here, as the friend to whom Babbage entrusted the task of making known to the world the principles of his analytical machine —a gigantic conception, the effort to realize which it is known was one of the chief objects of Babbage's later life. The latest development of this conception is to be found in the mechanical integrator of Prof. J. Thomson, in which motion is transmitted, according to a new kinematic principle, from a disc or cone to a cylinder through the intervention of a loose ball, and in Sir W. Thomson's machine for the mechanical integration of differential equations of the second order. In the exquisite tidal machine of the latter we have an instrument by means of which the height of the tide at a given port can be accurately predicted for all times of the day and night. The attraction meter of Siemens is an instrument of great delicacy for measuring horizontal attractions, which it is proposed to use for recording the attractive influences of the sun and moon, upon which the tides depend. The bathometer of the same able physicist is another remarkable instrument, in which the constant force of a spring is opposed to the variable pressure of a column of mercury. By an easy observation of the bathometer on shipboard, the depth of the sea may be approximately ascertained without the use of a sounding line.

The Loan Exhibition of apparatus at Kensington has been a complete success, and cannot fail to be useful, both in extending a knowledge of scientific subjects and in promoting scientific research throughout the country. Unique in character, but most interesting and instructive, this exhibition will, it is to be hoped, be the precursor of a permanent museum of scientific objects, which, like the present exhibition, shall be a record of old, as well as a representation of new inventions. It is often difficult to draw a distinct line of separation between the physical and chemical sciences; and it is perhaps doubtful whether the division is not really an artificial one. The chemist cannot, indeed, make any large advance without having to deal with physical principles; and it is to Boyle, Dalton, Gay-Lussac, and Graham that we owe the discovery of the mechanical laws which govern the properties of gases and vapors. Some of these laws have of late been made the subject of searching inquiry, which has fully confirmed their accuracy, when the body under examination approaches to what has not inaptly been designated the ideal gaseous state. But when gases are examined under varied conditions of pressure and temperature, it is found that these laws are only particular cases of more general laws, and that the laws of the gaseous state, as it exists in nature, although they may be enunciated in a precise and definite form, are very different from the

simple expressions which apply to the ideal condition. The new laws become, in their turn, inapplicable when from the gaseous state proper we pass to those intermediate conditions which, it has been shown, link with unbroken continuity the gaseous and liquid states. As we approach the liquid state, or even when we reach it, the problem becomes more complicated; but its solution, even in these cases, will, it may confidently be expected, yield to the powerful means of investigation we now possess. Among the more important researches made of late in physical chemistry, I may mention those of F. Weber on the specific heat of carbon and the allied elements, of Berthelot on thermo-chemistry, of Bunsen on spectrum analysis, of Wüllner on the band and line-spectra of the gases, and of Guthrie on the cryohydrates.

Cosmical chemistry is a science of yesterday, and yet it already abounds in facts of the highest interest. Hydrogen, which, if the absolute zero of the physicist does not bar the way, we may hope yet to see in the metallic form, appears to be everywhere present in the universe. It exists in enormous quantity in the solar atmosphere, and it has been discovered in the atmospheres of the fixed stars. It is present, and is the only known element of whose presence we are certain, in those vast sheets of ignited gas of which the nebulæ proper are composed. Nitrogen is also widely diffused among the stellar bodies, and carbon has been discovered in more than one of the comets. On the other hand, a prominent line in the spectrum of the aurora borealis has not been identified with that of any known element; and the question may be asked—does a new element, in a highly rarefied state, exist in the upper regions of our atmosphere, or are we, with Angström, to attribute this line to a fluorescent or phosphorescent light produced by the electrical discharge to which the aurora is due? This question awaits further observations before it can be definitely settled, as does also that of the source of the remarkable green line which is everywhere conspicuous in the solar corona.

I must here pause for a moment to pay a passing tribute to the memory of Angström, whose great work on the solar spectrum will always remain as one of the finest monuments of the science of our period. The influence, indeed, which the labors of Angstrom and of Kirchhoff have exerted on the most interesting portion of later physics can scarcely be exaggerated; and it may be truly said that there are few men whose loss will be longer felt or more deeply deplored than that of the illustrious astronomer of Upsala. I cannot pursue this subject further, nor refer to the other terrestrial elements which are present in the solar and stellar atmospheres. Among the many elements that make up the ordinary aërolite not one has been discovered which does not occur upon this earth. On the whole, we arrive at the grand conclusion that this mighty universe is chiefly built up of the same materials as the globe we inhabit. In the application of science to the useful purposes of life, chemistry and mechanics have run an honorable race. It was in the valley of the Clyde that the chief industry of this country received, within the memory of many here present, an extraordinary impulse from the application by Neilson of the hot blasts to the smelting of iron. The Bessemer steel process and the regenerative furnace of Siemens are later applications of high scientific principles to the same industry. But there is ample work yet to be done. The fuel consumed in the manufacture of iron, as, indeed, in every furnace where coal is used, is greatly in excess of what theory indicates; and the clouds of smoke which darken the atmosphere of our manufacturing towns, and even of whole districts of country, are a clear indication of the waste, but only of a small portion of the waste, arising from imperfect combustion. The depressing effect of this atmosphere upon the working population can scarcely be overrated. Their pale, I had almost said etiolated, faces are a sure indication of the absence of the vivifying influence of the solar rays, so essential to the maintenance of vigorous health. The chemist can furnish a simple test of this state of the atmosphere in the absence of ozone, the active form of oxygen, from the air of our large towns. At some future day the efforts of science to isolate, by a cheap and available process, the oxygen of the air for industrial purposes may be rewarded

with success. The effect of such a discovery would be to reduce the consumption of fuel to a fractional part of its present amount; and although the carbonic acid would remain, the smoke and carbonic oxide would disappear. But an abundant supply of pure oxygen is not now within our reach; and in the mean time may I venture to suggest that in many localities the waste products of the furnace might be carried off to a distance from the busy human hive by a few horizontal flues of large dimensions, terminating in lofty chimneys on a hill side or distant plain? A system of this kind has long been employed at the mercurial mines of Idria, and in other smelting works where noxious vapors are disengaged. With a little care in the arrangements the smoke would be wholly deposited, as flue-dust or soot, in the horizontal galleries, and would be available for the use of the agriculturist. The future historian of organic chemistry will have to record a succession of beneficent triumphs, in which the efforts of science have led to results of the highest value to the well-being of man. The discovery of quinine has probably saved more human life, with the exception of that of vaccination, than any discovery of any age; and he who succeeds in devising an artificial method of preparing it will be truly a benefactor of the race. Not the least valuable, as it has been one of the most successful, of the works of our Government in India, has been the planting of the cinchona tree on the slopes of the Himalaya. As artificial methods are discovered, one by one, of preparing the proximate principles of the useful dyes, a temporary derangement of industry occurs, but in the end the waste materials of our manufacturers set free large portions of the soil for the production of human food.

The ravages of insects have ever been the terror of the agriculturist, and the injury they inflict is ofter incalculable. An enemy of this class, carried over from America, threatened lately with ruin some of the finest vine districts in the south of France. The occasion has called forth a chemist of high renown; and, in a classical memoir recently published, M. Dumas appears to have resolved the difficult problem. His method, although immediately applied to the *Phylloxera* of the vine, is a general one, and will no doubt be found serviceable in other classes. In the apterous state the *Phylloxera* attacks the roots of the plant; and the most efficacious method hitherto known of destroying it is to inundate the vineyard. After a long and patient investigation M. Dumas has discovered that the sulphocarbonate of potassium in dilute solution fulfills every condition required from an insecticide, destroying the insect without injuring the plant. The process requires time and patience; but the trials in the vineyard have fully confirmed the experiments of the laboratory. The application of artificial cold to practical purposes is rapidly extending; and, with the improvement of the ice machine, the influence of this agent upon our supply of animal food from distant countries will undoubtedly be immense. The ice machine is already employed in paraffine works and in large breweries; and the curing or salting of meat is now largely conducted in vast chambers, maintained throughout the summer at a constant temperature by a thick covering of ice.

I have now completed this brief review, rendered difficult by the abundance, not by the lack of materials. Even confining our attention to the few branches of science upon which I have ventured to touch, and omitting altogether the whole range of pure chemistry, it is with regret that I find myself constrained to make only a simple reference to the important work of Caley on the Mathematical Theory of Isomers, and to elaborate memoirs which have recently appeared in Germany on the reflection of heat and light rays, and on the specific heat and conducting power of gases for heat, by Knoblauch, E. Wiedemann, Winkelmann, and Buff. The decline of science in England formed the theme, fifty years ago, of an elaborate essay by Babbage; but the brilliant discoveries of Faraday soon after wiped off the reproach. I will not venture to say that the alarm which has lately risen, here and elsewhere, on the same subject will prove to be equally groundless. The duration of every great outburst of human activity, whether in art, in literature, or in science, has always been short, and experimental sci-

ence has made gigantic advances during the last three centuries. The evidence of any great failure is not, however, very manifest, at least in the physical sciences. The journal of Poggendorff which has long been a faithful record of the progress of physical research throughout the world, shows no signs of flagging; and the Jubelband by which Germany celebrated the fiftieth year of Poggendorff's invaluable services was at the same time an ovation to a scientific veteran, who has perhaps done more than any man living to encourage the highest forms of research, and a proof that in Northern Europe the physical sciences continue to be ably and actively cultivated. If in chemistry the case is somewhat weaker, the explanation, at least in this country, is chiefly to be found in the demand on the part of the public for professional aid from many of our ablest chemists. But whatever view be taken of the actual condition of scientific research, there can be no doubt that it is both the duty and the interest of the country to encourage a pursuit so ennobling in itself, and fraught with such important consequences to the well being of the community. Nor is there any question in which this Association, whose special aim is the advancement of science, can take a deeper interest. The public mind has also been awakened to its importance, and is prepared to aid in carrying out any proposal which offers a reasonable prospect of advantage. In its recent phase the question of scientific research has been mixed up with contaminated changes in the great universities of England, and particularly in the University of Oxford. The national interests involved on all sides are immense, and a false step once taken may be irretrievable. It is with diffidence that I now refer to the subject, even after having given to it the most anxious and careful consideration.

A university, or *studium generale* ought to embrace in its arrangements the whole circle of studies which involve the material interests of society, as well as those which cultivate intellectual refinement. The industries of the country should look to the universities for the development of the principles of applied as well as of abstract science; and in this respect no institutions have ever had so grand a possession within easy reach as have the universities of England at this conjuncture, if only they have the courage to seize it. With their historic reputation, their collegiate endowments, their commanding influence, Oxford and Cambridge should continue to be all they now are; but they should, moreover, attract to their lecture halls and working cabinets students in large numbers preparing for the higher industrial pursuits of the country. The great physical laboratory in Cambridge, founded and equipped by the noble representative of the House of Cavendish, has in this respect a peculiar significance, and is an important step in the direction I have indicated. But a small number only of those for whom this temple of science is designed are now to be found in Cambridge. It remains for the university to perform its part, and to widen its portals so that the nation at large may reap the advantage of this well-timed foundation. If the universities, in accordance with the spirit of their statutes, or at least of ancient usage, would demand from the candidates for some of the higher degrees proof of original powers of investigation, they would give an important stimulus to the cultivation of science. The examples of many continental universities, and among others of the venerable University of Leyden, may here be mentioned. Two proof essays recently written for the degree of Doctor of Science in Leyden, one by Van der Waals, the other by Lorenz, are works of unusual merit; and another pupil of Professor Rijke is now engaged iu an elaborate experimental research as a qualification for the same degree. The endowment of a body of scientific men devoted exclusively to original research, without the duty of teaching or other occupation, has of late been strongly advocated in this country; and M. Fremy has given the weight of his high authority to a somewhat similar proposal for the encouragement of research in France. I will not attempt to discuss the subject as a national question, the more so as after having given the proposal the most careful consideration in my power, and turned it round on every side, I have failed to discover how it could be worked so as to secure the end in view. But whatever may be said in favor of the

endowment of pure research as a national question, the universities ought surely never to be asked to give their aid to a measure which would separate the higher intellects of the country from the flower of its youth. It is only through the influence of original minds that any great or enduring impression can be produced on the hopeful student. Without original power, and the habit of exercising it, you may have an able instructor, but you cannot have a great teacher. No man can be expected to train others in habits of observation and thought he has never acquired himself. In every age of the world the great schools of learning have, as in Athens of old, gathered around great and original minds, and never more conspicuously than in the modern schools of chemistry, which reflected the genius of Liebig, Wöhler, Bunsen, and Hofmann. These schools have been nurseries of original research as well as models of scientific teaching; and students attracted to them from all countries became enthusiastically devoted to science, while they learned its methods from example even more than from precept. Will any one have the courage to assert that organic chemistry, with its many applications to the uses of mankind, would have made in a few short years the marvellous strides it has done, if science, now as in mediæval times, had pursued her work in strict seclusion,

> Semota ab nostris rebus, seiunctaque longe,
> Ipsa suis pollens opibus, nil indiga nostri?

But while the universities ought not to apply their resources in support of a measure which would render their teaching ineffective, and would at the same time dry up the springs of intellectual growth, they ought to admit freely to university positions men of high repute from other universities, and even without academic qualifications. An honorary degree does not necessarily imply a university education; but if it have any meaning at all, it implies that he who has obtained it is at least on a level with the ordinary graduate, and should be eligible to university positions of the highest trust.

Not less important would it be for the encouragement of learning throughout the country that the English universities, remembering that they were founded for the same objects, and derive their authority from a common source, should be prepared to recognize the ancient universities of Scotland as freely as they have always recognized the Elizabethan University of Dublin. Such a measure would invigorate the whole university system of the country more than any other I can think of. It would lead to the strengthening of the literary element in the northern, and of the practical element in the southern universities, and it would bring the highest teaching of the country everywhere more fully into harmony with the requirements of the times in which we live. As an indirect result, it could not fail to give a powerful impulse to literary pursuits as well as to scientific investigations. Professors would be promoted from smaller positions in one university to higher positions in another, after they had given proofs of industry and ability; and stagnation, hurtful alike to professorial and professional life, would be effectually prevented. If this union were established among the old universities, and if at the same time a new university, as I myself ten years ago earnestly proposed, were founded on sound principles amidst the great populations of Lancashire and Yorkshire, the university system of the country would gradually receive a large and useful extension, and, without losing any of its present valuable characteristics, would become more intimately related than hitherto with those great industries upon which mainly depend the strength and wealth of the nation. It may, perhaps, appear to many a paradoxical assertion to maintain that the industries of the country should look to the calm and serene regions of Oxford and Cambridge for help in the troublous times of which we have now a sharp and severe note of warning. But I have not spoken on light grounds, nor without due consideration. If Great Britain is to retain the commanding position she has so long occupied in skilled manufacture, the easy ways which, owing partly to the high qualities of her people, partly to the advantages of her insular position and mineral wealth, have sufficed for the past, will not be found to suffice for the future. The highest training which can be brought to bear on practical science will be imperatively required; and it will be a fatal policy if that training

is to be sought for in foreign lands, because it cannot be obtained at home. The country which depends unduly on the stranger for the education of its skilled men, or neglects in its highest places this primary duty, may expect to find the demand for such skill gradually to pass away, and along with it the industry for which it was wanted. I do not claim for scientific education more than it will accomplish, nor can it ever replace the after-training of the workshop or factory. Rare and powerful minds have, it is true, often been independent of it; but high education always gives an enormous advantage to the country where it prevails. Let no one suppose I am now referring to elementary instruction, and much less to the active work which is now going on everywhere around us, in preparing for examinations of all kinds. These things are all very useful in their way; but it is not by them alone that the practical arts are to be sustained in the country. It is by education in its highest sense, based on a broad scientific foundation, and leading to the application of science to practical purposes—in itself one of the noblest pursuits of the human mind—that this result is to be reached. That education of this kind can be most effectively given in a university, or in an institution like the Polytechnic School of Zürich, which differs from the scientific side of a university only in name, and to a large extent supplements the teaching of an actual university, I am firmly convinced; and for this reason, among others, I have always deemed the establishment in this country of examining boards with the power of granting degrees, but with none of the higher and more important functions of a university, to have been a measure of questionable utility. It is to Oxford and Cambridge, widely extended as they can readily be, that the country should chiefly look for the development of practical science; they have abundant resources for the task; and if they wish to secure and strengthen their lofty position, they can do it in no way so effectually as by showing that in a green old age they preserve the vigor and elasticity of youth.

If any are disposed to think that I have been carrying this meeting into dream-land, let them pause and listen to the result of similar efforts to those I have been advocating, undertaken by a neighboring country when on the verge of ruin, and steadily pursued by the same country in the climax of its prosperity. "The University of Berlin," to use the words of Hofmann, "like her sister of Bonn, is a creation of our century. It was founded in the year 1810, at a period when the pressure of foreign domination weighed almost insupportably on Prussia; and it will ever remain significant of the direction of the German mind that the great men of that time should have hoped to develope, by high intellectual training, the forces necessary for the regeneration of their country." It is not for me, especially in this place, to dwell upon the great strides which Northern Germany has made of late years in some of the largest branches of industry, and particularly in those which give a free scope for the application of scientific skill. "Let us not suppose," says M. Wurtz, in his recent report on the artificial dyes, "that the distance is so great between theory and its industrial applications. This report would have been written in vain, if it had not brought clearly into view the immense influence of pure science upon the progress of industry. If unfortunately the sacred flame of science should burn dimly or be extinguished, the practical arts would soon fall into rapid decay. The outlay which is incurred by any country for the promotion of science and of high instruction will yield a certain return; and Germany has not had long to wait for the ingathering of the fruits of her far-sighted policy. Thirty or forty years ago, industry could scarcely be said to exist there; it is now widely spread and successful." As an illustration of the truths of these remarks, I may refer to the newest of European industries, but one which in a short space of time has attained considerable magnitude. It appears—and I make the statement on the authority of M. Wurtz—that the artificial dyes produced last year in Germany exceeded in value those of all the rest of Europe, including England and France. Yet Germany has no special advantage for this manufacture except the training of her practical chemists. We are not, it is true, to attach undue importance to a

single case; but the rapid growth of other and larger industries points in the same direction, and will, I trust, secure some consideration for the suggestions I have ventured to make.

The intimate relations which exist between abstract science and its applications to the uses of life have always been kept steadily in view by this Association, and the valuable reports, which are a monument to the industry and zeal of its members, embrace every part of the domain of science. It is with the greatest confidence, therefore, that I have ventured to suggest from this chair that no partition wall should anywhere be raised up between pure and applied science. The same sentiment animates our vigorous ally, the French Association for the Advancement of Science, which, rivaling as it always does this Association in the high scientific character of its proceedings, bids fair in a few years to call forth the same interest in science and its results, throughout the great provincial towns of France, which the British Association may justly claim to have already effected in this country. No better proof can be given of the wide base upon which the French Association rests, than the fact that it was presided over last year by an able representative of commerce and industry, and this year by one who has long held an exalted position in the world of science, and has now the rare distinction of representing in her historic Academies the literature as well as the science of France.

Whatever be the result of our efforts to advance science and industry, it requires no gift of prophecy to declare that the boundless resources which the Supreme Author and Upholder of the universe has provided for the use of man will, as time rolls on, be more and more fully applied to the improvement of the physical and, through the improvement of the physical, to the elevation of the moral condition of the human family. Unless, however, the history of the future of our race be wholly at variance with the history of the past, the progress of mankind will be marked by alternative periods of activity and repose; nor will it be the work of any one nation or of any one race. To the erection of the edifice of civilized life, as it now exists, all the higher races of the world have contributed; and if the balance were accurately struck, the claims of Asia for her portion of the work would be immense, and those of Northern Africa not insignificant. Steam-power has of late years produced greater changes than probably ever occurred before in so short a time. But the resources of Nature are not confined to steam, nor to the combustion of coal. The steady water-wheel and the rapid turbine are more perfect machines than the stationary steam engine; and glacier-fed rivers with natural reservoirs, if fully turned to account, would supply an unlimited and nearly constant source of power depending solely for its continuance upon solar heat. But no immediate dislocation of industry is to be feared, although the turbine is already at work on the Rhine and the Rhone. In the struggle to maintain their high position in science and its applications, the countrymen of Newton and Watt will have no ground for alarm so long as they hold fast to their old traditions, and remember that the greatest nations have fallen when they relaxed in those habits of intelligent and steady industry upon which all permanent success depends.

NOTE ON THE CONTINUOUS GIRDER DISCUSSION.

By MANSFIELD MERRIMAN, C. E., Ph. D., Instructor in Civil Engineering in the Sheffield Scientific School.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the August and September numbers of this Magazine we presented a paper on the theory of flexure as applied to continuous girders, reduced to a few simple formulae the determination of the moments and shears due to any assigned loads, and illustrated a simple method for the calculation of strains. While writing those articles, there appeared in the *Journal of the American Society of Civil Engineers* a paper which strongly and ably opposed the

present received theory of flexure, and particularly its application to the designing of continuous structures, and, as some of its deductions seemed to us to be founded in error, we took up incidentally a few of the arguments there advanced, and pointed out the defects of the reasoning involved. For example, we read on page 156: "if engineers assert that the deflections of their bridges agree with their calculations, either the first were erroneously calculated, or the second not well observed;" and again, on page 161: "the hypothesis of a constant modulus of elasticity of the material of a bridge being unfounded, the theory built on such hypothesis should be abandoned." Now, holding as we do, that the theory of flexure is of so great value that it cannot be abandoned until something better shall be furnished to take its place, we felt it our duty to analyze the reasoning which led to such extreme opinions, and to set forth in a clear light its hollow inconsistency and its utter worthlessness.

In our discussion of these points we were actuated only by a desire to help advance, in our humble way, the interests of engineering science; we had no thought of opposing, for the sake of opposition, the opinions of others, and least of all did we dream of invoking a personal controversy. And in the same spirit we pen this note as a supplement to our paper, and as a reply to an article in the last number of this Magazine, entitled "The Continuous Girder Question." Although this article, forgetful of the rules of literary discussion, indulges in personal innuendoes of a vituperative and slanderous nature, we shall overlook them in silence as not a matter of public interest, and leaving them to rebound, boomerang like, upon the source from whence they came, we shall confine ourselves strictly to the scientific questions at issue.

First, we have to correct an error contained in a passage on page 153 of our paper, where we said: "It is capable of demonstration that for girders subjected only to dead load, the total amount of strain in the webbing will be the same for simple as for continuous trusses." This is not accurate, for a slight difference usually exists, and the excess is always on the side of the continuous girder. For three equal continuous spans, this excess is theoretically 2.7 per cent.; the corresponding deficiency in chord strain is, however, 45.7 per cent., showing a total gain of 43 per cent. for the continuous beam. The following table shows the theoretical percentages for seven equal spans, the first containing the losses in the web, and the second the gain in the chords of the continuous compared with the simple system, dead load being alone considered:

	Web.	Chords.
End span.....	0.5	38.5
2d "	0.3	61.9
3d "	0.02	60.8
4th "	0.	61.7
All 7 spans.....	0.24	54.85

So that the total gain is about 54 per cent. By slightly decreasing the length of the end spans relatively to the others, the continuous girder becomes even more economical as far as dead load is concerned. These figures are, of course, materially altered by the strains due to the live load.

In our paper, near the bottom of page 148, wl_2 is inadvertently printed, instead of wl^2; and near the top of page 156, E I occurs instead of 6 E I. These and one or two other misprints of less importance are corrected in the re-issue, which forms No. 25 of *Van Nostrand's Science Series.*

We come now to speak of the article on "The Continuous Girder Question." First we shall examine one or two specific points, and secondly treat of the general question at issue. Our remarks shall be brief.

On pages 292–293 of that article we read: "I do *not* advise 'to abandon the theory of flexure,' and therefore I am *not* inconsistent if I apply it towards calculating the moduli from experiments on flexure. There is no passage of this kind in any of the papers written by me." Let this be compared with the quotations in our opening paragraph, which distinctly assert that "the theory should be abandoned," and in connection with our exposure of how that reasoning goes round in a circle, the situation be-

comes not merely interesting but ludicrous.

On page 293 we read: "And this, my conclusion, is justified, because these structures are *not any more, and even less, economical* as regards *quantity of material*, and in regard to *quality are decidedly inferior* to single span bridges of proper proportions and details." This sentence, in which the italics are not ours, forms a paragraph by itself, and in the one immediately preceding is the conclusion referred to, viz.: "that practical bridgemen who have not yet studied deeply the subject of continuous bridges, need not regard them seriously." By such logic as this is the engineering profession asked to decide the question under discussion!

The algebraical deduction on page 299 contains a *petitio principii* of a more subtle character. But by substituting "practically we have, $d=12$ millimeters," for "practically we do receive, E.I.d, $=\frac{1}{2}A_1(x_1^3-l^2x_1)$—etc.," it becomes evident, and renders what follows of slight value. And even if this be granted, it must be proved, and not assumed, that the slight variations of I and p, which scarcely influence the reaction, do not affect the far more delicate deflection.

We pass to the more general question under discussion, which may be thus stated: Is it expedient to construct continuous bridges, and if so, are they more economical than single spans? The position advanced in our previous paper, and which we still maintain is, that this question is not yet decided, and that it cannot be settled by theory, but only by actual trial; and since common sense, founded on experience, teaches us that a long continuous beam is better than several short single ones, and since the theory of flexure (often verified by experiment, and accepted by all scientists as a good working theory) indicates a large saving by the use of the continuous truss, that therefore it is well worth the while now and then *to try*. The position of the articles on the other side is, that the theory is a dangerous thing, that the question is already settled, and "that continuous girders are inferior to single spans in *every* respect" (page 292).

Concerning the amount of material saved by the use of the continuous truss, there is a wide diversity of opinion. In our paper, we have stated the theoretical percentage at from twenty to forty per cent., varying with the lengths of spans, form and height of truss, and ratio of live to dead load. We have granted that some of this must be deducted for increased difficulties of erection, extra care in workmanship, etc., but we further say (page 260): "How much of this must be deducted [for these causes] can only be determined by the actual erection of continuous bridges, by experiments extending through a long series of years." Other writers place this theoretical percentage of gain at higher figures. For instance, DuBois gives thirty to fifty per cent. for long spans (*Elements of Graphical Statics*, p. 376); Weyrauch claims from twenty-five to fifty per cent. (*Theorie der Träger*, p. 155); while Culmann finds even greater economy (*Die graphische Statik*, p. 540). Some writers give estimates of the actual saving, but with this, as we have said, theory cannot deal, and, in fact, we find wide variations in such estimates. While a standard writer like Winkler regards the actual saving in the trusses at from twenty-two to twenty-seven per cent. for spans of from three to five hundred feet, the opponents of the system allow no percentage, and claim that in practice it becomes negative.

We regard, then, the continuous girder discussion not as settled, but as open to much further careful inquiry and experiment. If the experience thus far of Germany or France or Austria had shown that "Continuous girders are inferior to single spans in *every* respect," we should be the last to suggest their trial elsewhere. But even there the discussion is rife, and both kinds of bridges are still built. Our interest in the matter is purely scientific, and whatever be the final decision, we shall accept it gladly. If in time it be demonstrated from these and other experiments that in some cases continuous girders are the best, we shall be glad; if it be demonstrated that they are in no case the best, we shall also be glad,—for in either event will engineering science and engineering art be placed upon a firmer foundation than they now occupy.

There is a personal paragraph on page 300 of the last number of this Magazine,

to which a feeling of literary pride compels us to allude. It is there charged that the formulae and methods of our paper, by which the investigation of continuous girders is so much facilitated, have been "simply compiled from the myriad of books and articles on continuity;" in other words, have been stolen. This serious charge we meet by a prompt denial. The triangles on pages 148–149 of our paper, the formulae (I), (II) and (III), on pages 194–195, and their application to the determination of strains by the methods of pages 198–201 were worked out by us alone in 1874, and, with other valuable matter, published in this ENGINEERING MAGAZINE, vol. 13, pp. 65–73, in the *Jour. Franklin Inst.* iii, vol. 69, pp. 206–215, 255–268, and in the *London Phil. Mag.*, iv, vol. 50, pp. 179–191; and have since been quoted and referred to by other writers. If these triangles and their law of formation, or these formulae and their method of application, can be pointed out in any earlier publication, no one shall be more ready than we to give due credit to the first discoverer.

ON THE USE OF WOOD, SAWDUST, AND PEAT AS FUEL IN RE-HEATING FURNACES.

BY RICHARD AKERMAN, of the Stockholm School of Mines.

From "The Engineer."

WHEN fuel containing water is burned, the water may simply be converted into vapor or it may be decomposed by the red-hot carbon, hydrogen and carbonic oxide being simultaneously formed. If we suppose the fuel to have a temperature of five degrees C., which nearly corresponds to the mean temperature of middle Sweden, for every weight unit of water which is vaporized from the fuel $95+536=631$ heat units are required, to which has to be added the heat abstracted from the furnace by its being heated above 100 deg. C. But as this naturally depends on the temperature at which the gases escape from the furnace, it must be very different in the case of different furnaces, which is even true if we confine ourselves to re-heating furnaces, as is our intention for the present.

In order to estimate properly the quantity of heat lost with the watery vapor, it is necessary in the case of such furnaces to ascertain both the temperature which such gases have when they pass out of the generator, and that of the products of combustion when they leave the furnace itself. The temperature of the gases as they pass out of the fireplace or generator is, however, so variable, according as both different kinds of fuel and differently constructed generators are employed, that it may, perhaps, be considered impossible to arrive at any average temperature. Neither is it of any great importance for the object we have in view in this paper, on which account we shall confine ourselves to the temperature at which the products of combustion leave the furnace itself. This perhaps in our common "Koltorn" re-heating furnaces with a moderate heating space, may be taken at about 600 deg. C., and as the specific heat of watery vapor may be taken at 0.475, there is abstracted from the furnace with every weight unit of steam which is to found among the products of combustion not only the 631 heat units mentioned above, but also $600\times0.575=284$ heat units in addition.

Besides this true loss of heat of about 900 heat units for every weight unit of water, the presence of watery vapor in the gases is attended with the serious inconvenience that, as its specific heat is nearly double that of the other gases, the temperature of combustion is lowered in consequence of its presence, farther than is due merely to the consumption of heat occasioned by the production of steam. Finally, the presence of watery vapor in a re-heating furnace is undesirable, because it has an oxydizing action on the iron, the waste of which is,

therefore, increased by it. The reasons why it is necessary to adopt the Siemens-Lundin principle when a very high temperature is desired, and even desirable when a comparatively moderate temperature is to be attained, are evident. For both the last-named inconveniences which attend the presence of watery vapor entirely disappear in this way, when it is removed before the gases are led into the furnace, and even the loss of heat caused by the overheating of the steam may in this case be reduced to nothing; for if the gases before they leave the generator are made to pass through a sufficiently deep layer of fuel, their temperature need not exceed 100 deg. C., and the whole of the loss occasioned by the vaporizing of the water may therefore be limited in this case to 631 heat units per weight unit of watery vapor to be found among the gases.

In order to vaporize a weight unit of water under the circumstances just described, there are required when the carbon, as is desired in a gas generator, is burned only to carbonic oxide, 631: 2473=0.255 weight units of carbon, and the water contained in the fuel, even if a drier fuel is used for the first firing and no loss of heat is supposed to take place through the walls of the generator, cannot exceed 2473:631=3.92 times the weight of the carbon. But as there is no way of preventing loss of heat through the sides of a furnace in operation, the weight of water in a fuel used for generating gas can scarcely exceed 3.7 times the weight of the carbon existing in it, and it is necessary when such a fuel is used to mix with it in the beginning a drier fuel until the requisite temperature has been attained in the furnace. If we pass now to a consideration of the relations of heat which are found to exist when the water is decomposed by red-hot carbon in the fireplace to hydrogen and carbonic oxide, we find that the fireplace or generator loses in this way yet more heat, for besides the 631 heat units required for the vaporizing of the water, there are consumed in this case 29,638:9=3293 heat units; but it is in the case of gas furnaces, especially when they are not provided with condensers on the Siemens-Lundin principle, exceedingly advantageous to get the watery vapor decomposed in this way as completely as possible, for the hydrogen thus formed gives back, when burned in the re-heating furnace, just the same quantity of heat, 3293 heat units, and this development of heat takes place just where a high temperature is desirable, while the consumption of heat, on the other hand, goes on in the fireplace or generator where no very high temperature is required for any other purpose than the decomposition of the watery vapor now in question. For this a pretty high temperature in the generator is advantageous, for if it be not high enough the watery vapor is not decomposed.

The reason of this again is that the decomposition in question must take place by means of red-hot carbon, and the thicker the stratum of this which the watery vapor passes through the more completely is it converted into carbonic oxide and hydrogen; but as this decomposition, as we have seen, is attended with a considerable consumption of heat, it is evident that if the layer of fuel through which the gases developed in the generator must pass is thick, the red-hot, or in this case the active, portion thereof is thinner in the same proportion as the water contained in the fuel is greater, and the thinner the red-hot layer of carbon is, the less watery vapor is decomposed during its passage through it. If the layer of red-hot carbon is, from the diminution of heat caused by a great content of water, too thin, little or no water can be thus decomposed, but the burning goes on in the way first described with a moderate consumption of heat in the generator; but the layer of red-hot carbon may also under such circumstances be so thin that none of the carbonic acid first produced during the combustion is reduced to carbonic oxide. As, however, carbonic acid is incapable of further combustion, the carbon thus oxydized in the generator is of little use in the furnace in the case of common "Koltorn" re-heating furnaces, and of none at all in the case of Siemens-Lundin furnaces, and when the combustion goes on in this way no proper degree of heat can be obtained.

If we reckon how many weight units of carbon must be burned to carbonic oxide in order to develope the amount of heat which a weight unit of water occur-

ring in the fuel requires for its decomposition in the way just described, we find this to be $(3293+631):.2473 = 1.587$ weight units, which corresponds to sixty-three per cent. water (both chemically combined and hydroscopic) of the carbon occurring in the fuel; but, in fact, the fuel used in a gas furnace, if the whole of the water it contains is to be decomposed, may not contain so much water, for if the requisite temperature be obtained in the beginning by using fuel containing less water, so that it is required only to keep up the temperature by the use of the moister fuel, there is always a considerable loss of heat through the walls of the fireplace, and the content of water in the fuel, if it is to be completely decomposed, ought certainly not to exceed something more than fifty per cent., say fifty-five per cent. of the weight of the carbon.

Let us now see how the different varieties of fuel correspond to these requirements. Dry and well-carbonized charcoal may be supposed to contain with eighty-two per cent. carbon ten per cent. hydroscopic water, and the relation of weight between carbon and water is thus about 10:82, the water being 12.2 per cent. of the weight of the carbon.

Ordinary pitcoal may perhaps be reckoned to contain 81 per cent. carbon and 9 per cent. chemically combined water, to which comes to be added about 5 per cent. hydroscopic water, so that the relation of weight between the water and carbon in this case is about 14:81, the water being 17.3 per cent. of the weight of the carbon.

Peat is more variable in its composition than coal, and it is therefore difficult to fix on any average ratio for its constituents; but, if we limit ourselves to good peat, perhaps we may take it as containing after complete desiccation at 110 deg. C., about 57 per cent. carbon, 2 per cent. hydrogen, 36 per cent. chemically combined water, and 5 per cent. ash. In air-dried peat there is, however, 20 per cent. to 40 per cent. and even 50 per cent. hydroscopic water, and it may therefore be taken to contain with 40 per cent. carbon, 25 per cent. chemically combined, and 30 per cent. hydroscopic water. The relation of weight between water and carbon is thus in the former case 36:57, the water being 63.1 per cent. of the weight of the carbon, and in the latter 55:40, the water being 137.5 per cent. of the weight of the carbon.

Wood completely dried at 120 deg. C. contains about the same quantities of water and carbon. Air-dried wood contains besides about 20 per cent. hydroscopic water, and may thus be considered to consist of 40 per cent. carbon, 40 per cent. chemically combined, and 20 per cent. hydroscopic water. Newly felled timber, on the other hand, contains 50 per cent. hydroscopic water and upwards, and its composition may therefore be taken to be 25 per cent. carbon, 25 per cent chemically combined, and 50 per cent. hydroscopic water. The relation of weight between water and carbon is thus in completely desiccated wood 50:50 or 100 per cent. water; in air-dried wood 60:40 or 150 per cent. water, and in newly felled wood 75:25 or 300 per cent. water.

Sawdust which has been air-dried by heating while kept in suitable houses contains 27 per cent. to 30 per cent. hydroscopic water, while fresh sawdust commonly contains 50 per cent.; but sawdust is also to be found which contains 60 per cent. The water in the three cases just referred to is 177 per cent., 300 per cent., and 400 per cent. of the weight of the carbon.

It has been already pointed out that if a fuel containing water is to be burned in the generator in such a way that the watery vapor is completely decomposed, as is desirable in the case of a gas furnace, and carbonic oxide and hydrogen are formed, the quantity of water in the fuel must not exceed about 55 per cent. of the weight of the carbon. But of the varieties of fuel specified above, charcoal and pitcoal alone fall within this limit, but as far as charcoal is concerned, it often unfortunately happens that it contains so much water as to exceed 55 per cent. of the weight of the carbon.

The water contained in air-dried peat amounts to 137.5 per cent., and in air-dried wood to 150 per cent. of the weight of the carbon, and of course neither of these kinds of fuel, and much less undried wood, which contains three times as much water as carbon, is fit to be used alone in such gas furnaces as are not

provided with condensers, but when they are used for this purpose they ought to be mixed with charcoal or pitcoal, as is generally done. Thoroughly desiccated wood, and still more peat, are much to be preferred in this respect, inasmuch as the former contains water to 100 per cent., and the latter to about 63 per cent. of the weight of the carbon; but even in the case of good peat, well dried by artificial heat, the whole content of water cannot be decomposed without the admixture of some fuel containing less water.

If the quantities of carbon and water contained in different kinds of fuel are known, it is of course very easy to ascertain how much of a fuel poor in water must be added to another fuel rich in water in order that the whole of the water contained in the mixture may be decomposed, provided the generator is properly constructed. On the supposition that the percentages of carbon and water in the different fuels are those stated above, the proportions reckoned by weight are as follows:—15.9 per cent. charcoal with 84.1 per cent. thoroughly desiccated peat; 17.7 per cent. pitcoal, with 82.3 thoroughly desiccated peat; 51.3 per cent. charcoal, with 48.7 per cent. thoroughly desiccated wood; 54.4 per cent. pitcoal, with 45.6 thoroughly desiccated wood; 65.8 per cent. charcoal, with 34.2 thoroughly air-dried peat; 68.6 per cent. pitcoal, with 31.4 thoroughly air-dried peat; 68.9 per cent. charcoal, with 31.1 per cent. thoroughly air-dried wood; 71.7 per cent pitcoal, with 28.3 per cent. thoroughly air-dried wood; 84.8 per cent. charcoal, with 15.2 per cent. undried wood; 86.7 per cent. pitcoal, with 13.3 per cent. undried wood.

These figures, however, denote, as has been said, only the greatest proportion by weight in which the above-mentioned fuels abounding in water may be mixed with those which contain less water, if the whole content of water is to be decomposed in a properly constructed generator, or, in other words, if the moist fuel is to be utilized as advantageously as possible without condensing; but it is clear that there is nothing to prevent the fuels containing much water to be used in smaller proportions than those stated above, and it may sometimes be advantageous, if not in a technical, at least in an economical respect, to allow them to enter into the mixture in a somewhat larger proportion, if the difference in price between them and the fuels containing little water is considerably greater than is due to their true value as fuel. It ought, however, in this case to be kept in mind that the moist fuel may be utilized with greater advantage by being used in a furnace according to the Siemens-Lundin principle, for when the mixed fuel contains so much water that a considerable proportion of it, even with a properly constructed generator, cannot be decomposed, a condenser may with great advantage be placed between the generator and the furnace, but it is then clear that regenerators must be employed for the re-heating of the gas. It is also to a considerable extent on this account that even the consumption of thoroughly desiccated wood in an Ekman wood re-heating furnace is so much greater than that of only air-dried wood in a Siemens-Lundin furnace, so that per centner of bar iron there are required in the former five cubic feet thoroughly desiccated, and in the latter three and a-half to four cubic feet air-dried wood.

As the water does not require to be decomposed when a Siemens-Lundin furnace is employed, there may be utilized in this way a fuel containing water to about 3.7 times the weight of the carbon, and accordingly it answers very well to use in such a furnace common fresh sawdust containing about three times as much water as carbon; but, on the other hand, it does not do, as we learn by experience, to use such sawdust as contains sixty per cent. hydroscopic water as sometimes occurs, for it contains about four times as much water as carbon. Such fuel as the last named can not of course come in question for employment in the re-heating furnace, if the Lundin furnace is not used. This furnace is also best adapted for wood, branches and peat, but if the supply of this fuel is not sufficient by itself it can, however, as is the common practice, be mixed with pitcoal and used in "Koltorn" furnaces. But in this case it is best thoroughly to desiccate it, as may in most cases be done by the waste heat of the furnaces, and that the value of the fuel is thereby much increased is shown by the fact that at Bjoerneborg

thoroughly desiccated condensed peat is considered to produce the same effect in the "Koltorn" furnace as one and a-half times its volume of charcoal; while machine-worked "pipe" peat merely air-dried is only considered to be equal to its own volume of charcoal, and air-dried "hand" turf is commonly reckoned to have half the value of its own volume of charcoal, all in "Koltorn" furnaces.

As an example of the way in which large quantities of undried inferior fuel may be used quite unnecessarily, it may be stated that at one place there was consumed in a "Koltorn" re-heating furnace per centner rolled iron, not only 0.434 cubic foot pitcoal but along with it 0.492 cubic foot imperfectly dried "hand turf" and 0.548 cubic foot refuse wood, while at another work under quite similar circumstances, in a furnace of the same construction, there was required per centner bar iron for the re-heating 0.38 to 0.40 cubic foot pitcoal without admixture with any other fuel. It appears to follow from this that the mixture with turf and wood at the former place was not only not advantageous, but that in fact some extra coal was consumed to counteract the injurious effect of the large quantity of water contained in the inferior fuel. I hope no one will understand me as seeking to oppose the employment of peat, refuse wood and other inferior fuel in re-heating furnaces, for, on the contrary, it is my view that re-heating in this country ought to be carried on with such materials; but we must either properly dry such fuel if we wish to mix it in any considerable quantity, for use in "Koltorn" re-heating furnaces, or go to the expense of Lundin furnaces if we wish to use it undried.

We have shown above what is the maximum quantity of water that a fuel can contain if the whole of the water is to be decomposed in the fireplace. When the content of water exceeds this limit, we must content ourselves with having that portion of it which cannot be decomposed, vaporized, and if the quantity of water is so great that it amounts to three times the weight of the carbon, the heat developed by the burning of the carbon to carbonic oxide is scarcely sufficient to decompose any water. In such circumstances, the Siemens-Lundin principle must be taken advantage of, if a proper heat is to be attained, and the generator ought to be so constructed that the gases before they leave it are obliged to pass through so large a quantity of fuel that their temperature is reduced to 100 deg. C. by drying and heating the upper layers of fuel. The generators ought in these circumstances to be as high as possible, and the openings for drawing off the gas close to the top of the generator.

When it is intended that the water in the fuel should be decomposed as completely as possible, it is not advisable, on the contrary, to allow the gas to pass through the whole mass of fuel for the result of this would naturally be, as in the case referred to above, that the greater part of the water would leave the generator undecomposed, but the opening intended for the escape of the gas must, in these circumstances, be placed so that the fuel near it is red-hot, and so decompose the watery vapor yet occurring in the gas: but this opening ought not to lie so near any tuyere that the carbonic acid formed in front of it is not converted by the red-hot fuel into carbonic oxide. These conditions for a proper combustion are fulfilled in a superlative manner in the Ekman "Koltorn" re-heating furnaces, which, in their old form with three rows of tuyeres, stand even higher in this respect than many recent modifications of them.

That it has been found advantageous at several works to depart from the old arrangement of the tuyeres, and they have instead been so placed that the gas before its entrance into the furnace proper has not to pass through so much red-hot fuel, doubtless arises from the fact that so much fuel abounding in water has begun to be used, that the whole of the watery vapor cannot possibly be decomposed by the amount of heat developed in the generator, and it is evident that under such circumstances it is best to take an intermediate course between the two types of generators referred to above. A generator on a new principle has been constructed by Herr Thum for the purpose of obtaining with certainty gas free from water and carbonic acid; and although it cannot be employed according to the inventor's statement for fuel containing so much water as thoroughly desiccated wood,

it may be useful for fuel containing a smaller quantity of water. In this generator there are two fireplaces connected together.

Fuel is charged into these alternately, and when a charge of fuel is placed in one fire-place the products of combustion are made to pass through the layer of red-hot fuel in the other, the direction of the blast being changed with every charge of fuel. In this way water and carbonic acid are reduced to hydrogen and carbonic oxide, and a dry gas with a constant high heating power obtained.

From what has been stated above it is evident that the fuel used in such a generator cannot contain more water than between fifty and sixty per cent. of the weight of the carbon present, for if it exceeds this the fire cannot be kept up so as to decompose the water as completely as is claimed for this arrangement.

THE CONSTRUCTION OF WELLS.

By JOSEPH LUCAS, F.G.S.

From "The Architect."

The frequency with which prosecutions of owners of polluted wells by sanitary authorities are recorded in the police reports sufficiently evince the growing determination on the part of the authorities to do away with such preventible causes of disease. There is no more unpopular subject among householders than that of wells; no one likes to be told that his well is foul and the water unfit for use, and yet there are comparatively few wells, even among the better class of houses, in which the sanitary conditions are all that they should be. On the other hand, the extent to which the opposite conditions prevail would hardly be credited. In the vast majority of cases it still remains an unsavory truth that wells are exposed to a dangerous pollution from the influx of sewage, either by leakage and filtration from the cesspool, or by direct conduction through a dry or absorbing well. It is almost superfluous to state that a dry well is one which is sunk to a depth short of that at which water is found, and notwithstanding the obvious contamination that arises from draining into such wells, they are even now constantly being sunk. The subject of wells, if discussed in all its bearings —physical, legal, and sanitary—would form a work that would be sufficiently voluminous, and I therefore propose to limit the present article to the consideration of such points as appear to be more especially of interest to the architects. The subject is a difficult one, but neither its difficulties, which are real, nor its importance, which is vital, have met with due regard from the architects of the past. I am justified in attaching responsibility to the architect, for when a house is built from his designs the well, if any, is included in the specification. It is, therefore, clear that the state in which our domestic wells exist at the present time is due to the architect. He is often called upon to build a house, find water for it, and drain it, within a very limited area. In such places surface drainage is generally out of the question; there is, therefore, no other course open but that of draining into a cesspool or dry well, which never is carried to any considerable distance from the house. Notwithstanding this, in probably ninety per cent. of cases the well is sunk either under a back kitchen or in a yard close to the house, in the entire absence of any evidence as to the nature of the geology of the point in question.

The geological points that demand mature consideration before the (1) site of a well, and (2) the relative positions of well and cesspool should be determined, are—

1. The knowledge of the geological section that will be traversed in sinking the well. This will include

a. The surface geology,
b. The solid geology,

and is of the utmost importance. For

instance, where there is a superficial covering of gravel, that is often made use of to drain into, either directly by a dry well a few feet deep, or a cesspool is built in it, which may leak or overflow, and so contaminate the gravel. The well for water, perhaps, goes deeper, possibly through a bed of clay or shale to some waterbearing bed below, and this is taken as a sufficient provision against contamination of the deep or "main springs" by the dry well or cesspool in the gravel. Consequently the well is "steined" without cement, with a view only to supporting its sides, and a system of contamination is thus set up which goes on for years, working insidious harm upon the constitution of the dwellers in the house. This is no imaginary case. I have known a house in which, under the above conditions, the soakage from a dry well flowed into the deep well water below, in which, from being much diluted, it escaped detection for years.

The "surface geology" includes all superficial deposits of drift, clay, gravel, sand, &c., lying in patches on the rocks included in the "solid geology," which means all the strata which form the geological scale, of tertiary age and older.

In respect of the solid geology it is a point of vital moment to know the direction of the dip of the beds, and, therefore, in most cases, the direction in which the water will flow (excepting, in fact, that of a basin in which the sides are of unequal height, when the water flowing out over the lower side will be forced to flow up the dip). The knowledge of the direction of flow is essential, as without it the relative positions of the cesspool (if any) and of the well cannot be determined. I have before me many cases in which the well is placed on the low side (in respect of the flow) of farm-yards and houses on the chalk, from which contamination must inevitably arise. To avoid risk of contamination, the cesspool should always be placed on the side of the well towards which the water is flowing. Hitherto the architect has not advised himself as to these difficult points. Nor is this surprising. Until very recently little attention has been given to the sanitary issues, but now, under the pressure of the advance in modern sanitary science, it is held to be indispensable that every well that is in use must yield water which on chemical analysis is found to be sufficiently pure for domestic purposes.

The cases will be exceptional ones in which the architect of the future will be able to include the well in his specification without having first submitted the question of its existence and of its position to a competent authority. No one man can undertake such a vast variety of work, or can pretend to be master of so wide a range of knowledge, as the architect assumes when he embraces the wide question of subterranean hydrology in addition to his own subject. There is a growing tendency to close as many wells as possible, arising partly from the dreadful state of pollution in which they are so often found, and partly from the pressure put on by water companies to bring such cases to light.

The state of the law favors such a result. The law in this case is weak, inasmuch as it divides the power of dealing with a polluted well between the magistrate and the local authority. The consequence is that the magistrate exercises his right of ordering the well to be closed, and the local sanitary authority, having disposed of the case, does not care to proceed to exercise its powers, and see that the defective drains, cesspools, or other sources of contamination are made right.

This tendency to close all wells becomes a serious matter, considering the outlay upon them. No man likes to see his work upset, but unless very speedy and certain steps are taken by the architect to protect the wells of the future they will assuredly share the same fate. It is not an easy matter to know what to do with the sewage of a large, or even of a small house in a limited space, which has also to provide the water supply. The temptation undoubtedly is to carry it into the inviting porous rock that most generally lies at an accessible depth. It is not easy to dispose of the thirty gallons per head per diem that may flush the drains of a large establishment. The well must at all events be protected, and we hold that it should be made an absolute principle in all future legislation on this subject, that it shall never be legitimate to sink or use any well for the pur-

pose of a drain. I regret to say that I can point to numerous instances in which the efflux of the house goes to replenish the well.

Next as to farms. There is hardly such a thing to be seen as a farmyard without its well. The water is often confessedly so foul that the farmer and his household will not use it, yet the cattle have it to drink, and apparently thrive on it till they pass into the hands of the butcher. We urge that the drainage of the farmyard should not be allowed to enter into the water-bearing stratum. We fail so see on what principle our gravels, our chalk, and our greensands, are made to imbibe sewage, when it is held to be illegal to discharge it into our rivers. Wells sunk through or in clay are not by any means safe against such contamination. It has been shown by me, in a report by Dr. Thorne Thorne to the Local Government Board, that deep cracks formed during the hot weather, act as channels through which the drainage of middens and privies finds access to shallow wells.

It is not necessary to add more to demonstrate the necessity of attention to a subject the importance of which is gaining ground every day, and of all interests involved, short of the owner's, that of the architect is most bound up in preserving in their native purity the deep springs which, in the hottest seasons, we draw so clear and cool from our wells.

THE VALUE OF IRON.

From "The Engineer."

THE letters of our correspondents in the ironmaking districts of Great Britain have been for months a record of disaster. The iron and steel trades were long since pronounced, week after week, to be as bad as they could be; but week after week the statement has been falsified by events, and at this moment the iron trade of the Middlesbrough district, at all events, is worse than it ever was. The evil is not limited to a total dearth of orders at anything like remunerative prices. Firms a few months ago perfectly solvent are now said to be on the verge of bankruptcy; failures are announced every day; credit is contracted to the ultimate point beyond which it must be totally extinguished; and there is no evidence whatever that any change for the better is likely to occur in the immediate future. Wales, Staffordshire, and Scotland are but a shade better off. It is time that men looked facts plainly in the face, accepted the new conditions which have sprung into existence, and determined to make the best of them. Bad as matters undoubtedly are, it may, we think, be shown that the iron and steel trade of this country is by no means in a hopeless condition. But before any steps can be taken to place it on a sound footing it is essential that we should estimate iron at its true value. Until this is done by masters and men alike, no amelioration of the existing state of affairs can possibly take place. The principal source of our trade troubles lies in the fact that a fictitious value has been attached to iron—in great measure as the result of a remarkable temporary demand. In order to arrive at the true value of the metal all such abnormal requirements must be disregarded, and if this is done, it will be found that even at its present low price iron is too dear. It is quite unnecessary here to repeat the history of the iron trade during the last few years. We shall confine our attention to the statement we have made concerning the value of iron, and endeavor to show that even if the price were reduced considerably below existing figures it would not follow that much loss would result to the nation.

A law of political economy, the accuracy of which has often been disputed in spite of facts, is that the value of a commodity is settled by the wishes or the necessities of the consumer, the producer having very little voice in the matter. Of course, conditions may arise under which the rule is inverted, but this can only be the case when the means of production are very small, and the consumer is compelled by his necessities to buy. The price of bread in a beleaguered city

may be cited as an example. As regards iron, however, the price—in other words, the value—of the commodity is determined by the consumer. In dealing with the subject in a recent article, we pointed out that no reduction in the price of iron would be likely to renovate the iron trade, and we repeat the assertion here. Although we shall endeavor to show in a moment that, without a reduction in the price of iron, it is to the last degree unlikely that we can get back our markets, the two propositions are only apparently incompatible. Some years since the consumer fancied that he wanted iron very much, and in consequence he bought it. He consented to pay a long price for it. In other words, he raised its value. As a matter of fact the consumer was mistaken. He bought a great deal more iron and ordered a great deal more than he required. Railways were planned, and even made in whole or in part, where they could not prove remunerative speculations. Ships were built in excess of all reasonable requirements. Iron furnaces were erected on speculation, and large sums were invested in rolling mills. By and by the reaction came. It was discovered that much more iron was possessed by the world than the world could use at once. The demand fell off as rapidly as it came, and with lamentable consequences. Until the existing stock of iron has been in part at least used up, it is impossible that the value of the metal can increase, and it is difficult to see how, under these circumstances, any reduction in the price of iron could put the trade on a sounder footing. It must be borne in mind, however, that in saying this we are dealing with the present, and with the present only. There is an almost total absence of demand for iron just now. This is not the case in England only. The iron and steel trade of the United States is in a prostrate condition. America possesses at this moment all the finished iron she wants. Why should she buy until the stock is gone? In Germany matters are, if possible, worse than they are here. A large number of the ironworks have already been closed, and by the end of the year the list will be augmented. Turn to what part we may of the civilized world, the prospect is the same. The production of iron is being diminished. The demand has practically ceased to exist, and, we repeat here, that until some of the large quantities of surplus iron made in 1869 and the immediately succeeding years, have been worked off, it is not likely that the demand for new iron can reach the average. It is not to be supposed that the iron exists in the form of bars or plates. It has been worked into ships which are practically unsaleable just now. It is to be found on our railroads. It has gone into roofs and girders, and into machinery for which no purchasers can be found. It may be admitted that the present decline in demand is not wholly due to the abundance of manufactured iron in the world. No doubt the total stagnation of gold and the absence of speculation work to the same end. But over production in past years is indubitably so powerful an evil influence at the present moment, that to it, in very large part, is due the calamitous aspects of our iron trade. In other words, had not iron been produced in excess, the daily demand which would otherwise have to be satisfied would have kept our works fairly employed. Iron rails, and wheels, and machinery, and ships will wear out, however, and an increased demand will no doubt spring up ere long. But it is very unlikely that the price of iron will ever, within the present generation, touch the point it reached in 1873.

That the value of manufactured iron may yet be as much as £1 per ton less than the price now accepted to secure a good order for ordinary bars or rails is, we think, not improbable. It by no means follows, however, that the result will be disastrous to the country. The production of iron in quantity is no longer confined to England. Our exports must decrease year by year, unless we are able to undersell our rivals. But, after all, cheap iron really means cheap coal and cheap labor, and provided colliers and ironworkers are content to accept less wages, there is no difficulty in the way of selling plenty of iron in time to come at remunerative prices. Practically the entire value of coal and iron is represented by labor. So long as the ore lies in the mine it is worth nothing. It is rendered worth something by the work expended in obtaining it. If

the value of labor is reduced, that of the finished article resulting from the operations of the workman can also be reduced. It will be argued, no doubt, that if we receive less money from foreign consumers than we have done before, we shall be considerable sufferers. The answer to this is, that a reduction in the price paid for labor does not necessarily entail loss to a community. A fall in wages in one important branch of trade is followed in time by a fall in most other trades, and the net result is an increase in the purchasing power of gold.

The lesson conveyed by the recent events is easily understood. Manufacturers must consent to accept the inevitable. They must agree to a still further reduction in the price of iron, and they must limit production for some time to come. But it is impossible to effect any reduction in the price of iron without a corresponding reduction in the price of labor. In such a reduction lies the only hope of the ironmaster. Month after month he has gone on, hoping against hope for an augmented demand. It is hard to believe that iron is worth so little as it really is just now, but the truth is apparent to every unprejudiced person. The immediate future of the iron trade of this country is, as we have said, for the moment absolutely in the hands of the consumer, and as he does not want iron, no reduction in price could augment the demand. But a time will come when demand will spring up again, and then we must be prepared as a nation to encounter a keen competition.

REPORTS OF ENGINEERING SOCIETIES.

CIVIL ENGINEERS' CLUB OF THE NORTHWEST. —The regular meeting of the Club was held Oct. 3d. President Chesbrough in the chair.

Chas. Paine, Past President, read the paper for the evening, entitled "*A French Railway Charter*," which was listened to with great interest by the society, and afterwards briefly discussed by Messrs. Paine, Chesbrough, Greeley, Morehouse, Hjortzberg and Clarke. The paper was a free translation by Mr. Paine, of the model from which, with alterations to suit the exigencies of each case, the Charters for French Railways are drawn, and is particularly illustrative of the very paternal character of that government. The date of the original from which the translation is made is as recent as 1872.

Mr. H. W. S. Cleveland made a partial report of the proposed arrangements for testing the merits of the Divining Rod, by Chas. Latimer, C. E.

IRON AND STEEL NOTES.

ON THE HARDENING OF STEEL.—The hardening process, which now plays such an important part in the steel industry, has been but imperfectly studied, and many false notions are prevalent in connection with it. This is shown by M. Jarolimek in a memoir recently published in the Austrian *Zeitschrift fur Berg und Huttenwesen*, in which he also communicates the results of an experimental investigation of the subject. It is ascertained, first of all, that under certain circumstances, not only boiling water, but also water of 150 deg. C. temperature, and more, and also boiling oil, hot liquid lead, tin, or even zinc—that is to say, a cooling liquid of some 400 deg. C. of heat—are capable of hardening steel.

This fact might appear the more remarkable, because it has been common to suppose, that steel, when hardened, must be quickly cooled to a much lower temperature, and it is also known that hardened steel loses its hardness considerably under action of a temperature of about 300 deg. Further, thin steel wires, which are made quite hard by a short immersion in hot liquid zinc, lose their hardness again if allowed to remain in the bath. It is sufficient to infer from this, that the hardness of steel chiefly depends on the rapidity with which it is transferred from a temperature of something over 500 deg. C. to one of something under 500 deg., or, so to speak, on the quickness of extinction of its glow, effected by exposing it to a temperature within other limits. When this is recognized, the availability of fused metals for steel hardening need not any longer cause surprise; and the less would it do so if it were supposed that the hardness of steel depends only on the temperature and the heat conductivity of the cooling liquid. For from this point of view the metals above referred to, even when heated to fusing, must ever have a greater hardening power than water. But although these metals really harden steel, their hardening power, as M. Jarolimek has found from many experiments, is far from reaching that of water. The reason is, that not only the temperature and the heat conductivity of the liquid affect the hardening power, but also its capacity for heat, the height of its boiling point, and, with low boiling point, also the amount of latent heat of the produced vapor. Proof of this is had in the fact, among others, that spirit of wine, which easily passes into vapor, but takes only a small amount of latent heat, hardens steel badly; and as regards water especially, this can, according to M. Jarolimek, harden steel only through formation of vapor, so that its heat conduction is only of secondary importance, though it always has a certain *role* in the hardening process.

In the immediate neighborhood of a metal heated to 1000 deg. C. or even to 500 deg., the temperature is one at which water, under ordinary pressure, cannot remain in the liquid state, but must be quickly transformed into steam.

Hence it follows that also the steel to be hardened, so long as it has the above high temperature, and it retains it (according to what has been said) till the commencement of its hardening, cannot enter into immediate contact with the water, but, till its further cooling, must remain sheathed by a layer of vapor. This sheathing of hot steel by a vapor layer may be very easily perceived when a glowing piece of wire is introduced into hot water. As water heated to near the boiling point very readily passes into steam, a pretty strong steam-layer is formed about the wire, and during extinction of the latter is slowly lost from below upwards.

Under these circumstances, however, the steel cannot, of course, yield up its heat immediately by heat conduction to the water; but since the steam in the interval cannot, with so slight pressure, be much heated, the yield of heat to the water takes place principally through radiation, and the wall of water separated by the steam from the steel then develops vapors constantly and by rapid vaporization, which vapors pass to the upper water-layers and are there condensed. These considerations have an eminently practical, as well as a theoretical interest, for they lead to essentially new and rational processes for the hardening of steel. The perception, namely, that formation of vapor promotes the hardening process, since it takes up a great deal of heat in its production, teaches that only a little water is needed for hardening of steel, and that it is very important so to arrange that the vapor formed is very quickly removed, so that new vapors may be rapidly formed

We will not here further enlarge on the practical consequences of these principles, and will merely state that four methods of hardening steel may be deduced, viz., the hardening by slow immersion, by action of a stream of water —two methods formerly known—further, the hardening by sprinkling, and by the action of water dust. These two latter new methods are very advantageous on account of the small use of water. Lastly, it may be mentioned that the knowledge that hardening occurs, even with a temperature of 500 deg., and 400 deg., has led to the adoption of that mode of hardening in which the steel is first quickly, then slowly, cooled; it is thereby hardened in the first stage, and annealed in the second. Various modifications of the methods make it possible to regulate the whole process in any desired way, and always reach the degree of hardness intended.

On the Uchatius Steel Process at Wikmanshytte, Sweden.—In this process, steel is produced by fusing, in crucibles, a mixture of finely divided cast iron with pure rich iron ore which has been previously roasted and reduced to powder. The pig iron, which is from one-third to one-fourth white (Swedish classification ?), is granulated by running it when melted into a bucketed wheel which revolves at a high velocity in water. The ore is the best quality of calcined Bispberg magnetite, stamped fine and sifted, care being taken to select only the very richest. These preparations are necessary to obtain the complete mixture of the ore and metal, essential for the production of steel of good quality. If the materials are imperfectly mixed, the steel is too hard and blows in the ingot. The proportions of metal to ore in the charge differ, of course, according to the nature and temper of steel required. It is usual to keep the weight of metal constant, and only to vary that of the ore.

The melting furnaces are of the ordinary Sheffield pattern, coke being used as fuel. Blacklead pots from the Battersea works, holding ½ cwt., are made red hot before charging, and they are surrounded in the furnace with charcoal, which communicates the fire to the coke. The bottoms of old pots are used as covers, and stands are used to prevent the adhesion of the slag formed by the coke, to the pot. If this should occur, the pot is so much cooled that it becomes impossible to command a melting heat. Two pots are placed in each furnace, which usually makes three meltings per day.

As soon as the coke is well ignited the furnace is closed, for about an hour, in order to warm up the pots gradually; the draught is then increased by opening the damper at intervals of a quarter of an hour until it is completely open. About three and a half hours are required for complete fusion of the charge. The pots usually stand six meltings, but the number is mainly dependent upon the quality of the coke, which must be of the very best description. With the milder qualities, of course, only a smaller number can be got; thus in making No. 6, containing from 0.3 per cent. to 0.45 per cent. of carbon, which requires from seven to eight hours for complete fusion, the pots can only be used once.

The consumption of coke is about 71.5 bushels daily, when two furnaces, making three heats each, are in use, corresponding to about 11.6 bushels per cwt. of steel. Formerly a somewhat smaller quantity was required, the increase being due to the use of air channels in the brickwork for cooling the walls, which keep the furnace in shape, and allow them to run longer without repair than was peviously the case. The interior lining of the melting furnace is made of a mixture of coarse and fine quartz, old pots ground to a powder, but free from dust, worked up with a little fireclay in water. The lining lasts four days without repair; as soon as it begins to burn out, the holes are stopped with quartz bricks of about the same composition, air-dried and molded to fit. The bottoms of old melting pots are also used for the same purpose.

The steel is classified according to numbers; No. 02 being the hardest, and No. 3 the softest, milder numbers being only produced exceptionally. The intermediate numbers are 03, 1, and 2.

No.	3	contains from	0.7	to	0.85	per cent. of carbon.
"	2	"	"	0.85 "	0.95	" "
"	1	"	"	0.95 "	1.10	" "
"	03	"	"	1.10 "	1.20	" "
"	02	"	"	1.20 "	1.30	" "

No. 02 is used almost entirely for mill-stone dressing tools, but to a smaller extent for

razors. Nos. 03 and 1 are tool steels. The latter is also a first-class die steel, while No. 3 is best adapted for stone-cutting tools of all kinds.

RAILWAY NOTES.

RAILROAD FOG SIGNAL.—Among the many devices for stopping railroad trains by a signal from a distant station, is an electro mag netic apparatus recently examined and approved by the French Minister of Public Works. It consists of a steam whistle on the engine, closed by a valve governed by a spring that is controlled by a common electro-magnet. From the magnet extends a wire down the side of the engine, and ending in a steel wire brush about eight inches long, suspended just outside of and above the rail. At the signal post a small copper plate is set up about four inches from the rail, and on a level with the bottom of the brush on the engine; this is then connected with the signal service of the line

On passing the signal, the brush on the engine sweeps over the copper plate and makes an instant connection with the line. The magnet is at once released, and by means of the spring the valve is opened and the whistle sounds. The driver is thus warned of danger, whether he sees the usual signal or not, or in spite of them if they are disarranged. If every signal station is supplied with this apparatus, the driver may be ordered to run slow to the next signal, to stop there, or to go on if the road is clear, according to a pre-arranged system of signals, and all of this quite independently of the usual sight signals. The apparatus is reported to work with precision and certainty, and has been officially recommended to all the French lines.

THE DURABILITY OF IMPREGNATED SLEEPERS.—At the late meeting of German railway engineers at Constance, Privy Councillor Funk communicated some facts regarding the preservation of railway sleepers by impregnation. From observations made on the Cologne Minden Railway and on the Hanoverian State Railways, it appears that the durability of sleepers depends very much on the different methods of treatment to which they are subjected before laying down. The results obtained at the above railways showed that—

Pine sleepers, impregnated with chloride of zinc, after being in use for twenty-one years, required renovation in the proportion of 31 per cent. of those laid down:

Beech sleepers, impregnated with creosote, after a use of twenty-two years, in the proportion of 46 per cent.:

Oak sleepers, not impregnated, after seventeen years' use, in the proportion of 49 per cent.:

Oak sleepers, impregnated with chloride of zinc, after seventeen years, in the proportion of 20.7 per cent.

In all these cases the observations were made under exceptionally favorable circumstances, viz., the sleepers were embedded in good and clean ballast, perfectly drained.

Pieces cut out of sleepers remaining in the permanent way, after the lapse of the above periods of observation, showed perfectly sound cross sections.

In connection with the above highly satisfactory results obtained with impregnated sleepers on German railways, it may be mentioned that similar observations have been made for a number of years on an Austrian railway,—the Kaiser Ferdinands-Nordbahn. It appears from them that renovation was found to be necessary with

Oak sleepers, not impregnated, after a use of twelve years, in the proportion of 74.48 per cent.:

Oak sleepers, impregnated with chloride of zinc, after seven years, in the proportion of 3.29 per cent.:

Oak sleepers, impregnated with tar-oil, containing creosote, after six years, in the proportion of 0.09 per cent.:

Pine sleepers, impregnated with chloride of zinc, after seven years, in the proportion of 4.46 per cent.

The impregnated pine sleepers upon which the above observations were made were put down in 1869, in the stations of the Mahrisch-Schlesische Nordbahn. Since 1869 and 1870, only oak sleepers, previously impregnated with chloride of zinc or with tar oil containing creosote, have been in use on the Kaiser Ferdinands-Nordbahn.

THE cost of railroad construction has been so remarkably reduced within the last three years, that the roads now building will be able to do business at a great advantage over the older roads. Not only are numerous narrow-gauge roads being built at the rate of from $6,000 to $9,000 per mile, but the new standard gauge lines are costing, in many cases, scarcely half they would have cost ten years ago. The Columbus & Toledo Railroad, in Ohio, now rapidly approaching completion, while it is a first-class railway in respect to alignment, grades, ties, road bed and rails, and one half of the rails are of steel, has cost, it is said, on the average, only $15,000 a mile. If this rate is not exceeded when the whole 121 miles of the road are completed, the company will have an immense advantage over its neighbors in respect to cost and the consequent portion of its earnings required to meet interest on the original investment. To illustrate this we take at random from the report of the Ohio Railway Commissioners, the figures showing the cost of construction, without equipment, of several of the roads in that State:

Columbus & Toledo, as above reported	$15,000
Cincinnati, Hamilton & Indiana	26,000
Marietta, Pittsburg & Cleveland	36,526
Cincinnati & Muskingum Valley	37,319
Central Ohio	39,086
Columbus & Hocking Valley (of which the Columbus & Toledo is virtually an extension)	38,000
Cleveland, Columbus, Cincinnati & Indianapolis	54,018
Pan Handle & Youngstown	52,915
Little Miami	53,486
Cincinnati & Springfield	63,524
Cleveland & Pittsburg	64,487
Lake Shore & Michigan Southern	66,540
Cincinnati, Hamilton & Dayton	72,342
Cincinnati & Indiana	99,122

It is certain that if railroads can now be built at one-half, one-quarter and even one-sixth the cost of existing roads, the new roads ought to make money if the old can even live.

ENGINEERING STRUCTURES.

THE GREAT BLAST AT HELL-GATE.—The great explosion, so long talked of, was successfully and we may add in view of public expectation, *quietly* conducted on the afternoon of the 24th ult.

Work was commenced as far back as July, 1869, by building a coffer-dam between high and low-water marks. This dam was finished in October, and the sinking of a huge shaft immediately ensued. This shaft or pit, measured 117 feet in its greatest length, and sixty-two feet in its greatest width; the depth below low water was thirty-three feet. From the bottom of the shaft ten headings were driven. These radiated under the entire reef. They were from ten feet to twenty-two feet high, and of various lengths, the average being about 270 feet. These were connected again by cross galleries at every thirty feet. The galleries were roughly of the same section as the main headings or tunnels. The whole space was thus converted into a vast honeycomb, the roof of solid rock under the river being held up by the columns left to support it. These columns were finally reduced as much as was deemed prudent, by minor headings, until finally 173 piers were formed averaging about ten feet each in thickness. The entire reef, covering an area of three acres, was thus undermined. The aggregate length of tunnels and galleries driven under the bed of the river was 7425 feet. From the excavation, 47,461 cubic yards of rock were removed by drilling and blasting; this operation required 208,174 lineal feet or 39½ miles, of drill holes, of which 90,107 feet in depth were drilled by hand, and 118,067 feet by various kinds of machine drills, viz., the Burleigh, Diamond, Rand, Winchester, Wood, Ingersoll and Waring drills, worked by compressed air. The following quantities and kinds of explosives were used in blasting the rocks:—Blasting powder, 24,431 lb.; nitro-glycerine, 26,471 lb.; giant powder, 1932 lb.; mica powder, 600 lb.; vulcan powder, 4017 lb.; rend rock 1500 lb.—total 58,951 lb. In exploding these compounds, 63,756 exploders, and 331,516 ft, or 62½ miles, of Bickford's safety fuse were used. In all, about 75,000 blasts were fired. The usual method of driving a tunnel was as follows:—The face of the rock was pierced obliquely with as many drill-holes, from three feet to four feet in depth, as were deemed necessary; the charges were then prepared by placing the explosive in water-tight paper cartriges, from eight inches to twelve inches long, and containing from eight ounces to twelve ounces of explosive; into each of these cartridges was inserted a copper cap containing mercury fulminate, fastened to the end of a piece of safety fuse, generally about five feet in length. The cartridge was then pushed to the bottom of each hole, which was filled with water. The end of the fuses hanging from the drill holes were then ignited. The broken rock was then loaded upon small cars carrying about one-third of a cubic yard each, which were hauled by mules along a railway to a turntable near the middle of the floor of the shaft, where a derrick worked by steam hoisted the car body and its contents off the truck to the top of the shaft; and the rock there dumped into a tipping car, attached to a small steam locomotive, which conveyed the *debris* and deposited it at the end of the spoil bank. The excavations were completed in June, 1875, and since that period the piers and under surface of the roof were pierced with numerous blast holes, to effect the final demolition.

The destruction of the supporting columns was effected by exploding simultaneously a very large number of distinct cartridges placed in holes in the pillars. We do not hesitate to state that never before were so many isolated charges exploded at once as on the afternoon of the 24th of September, and very considerable difficulty was incurred in effecting electrical communication between them all and the batteries. The work of charging the holes in the columns began at half-past seven on the morning of the 12th inst., fifteen trustworthy men being picked out for the work. Three different explosives were used, namely, dynamite, rend rock, and giant powder, each supplied by a different company. The total quantity bought was about 57,000 lb., delivered in cartridges packed in boxes, each box holding 100 lb. The cartridges were metallic and all of the same length, about one foot eleven inches, but the diameter varied, four different sizes being used, 2½ in., 2 in. 1⅞ in., and 1¾ in. The average depth of the holes drilled in the columns was ten feet. It was found impossible to keep the bores of the same diameter throughout this distance, hence the necessity for the variation in the size of the cartridges. The smallest, containing about ten pound of explosive, was placed at the bottom or furthest extremity of the hole, and was succeeded by three other cartridges. The most powerful explosive was placed in the smallest cartridges. There were in all 4462 charged holes, containing 52,206lb. of explosives, and to avoid confusion, before the work of filling them began, wooden plugs were stuck into each hole, each of these plugs was fitted with a small tin disc bearing a number, and the plugs were united by cords running in the same direction as that afterwards taken by the conducting wires from the battery. When all the holes were charged, the electrical staff commenced operations, placing in each hole an exploding cartridge, about one foot long, and lined with vulcanite. In each cartridge was a small brass cylinder two inches long and five-eighth inch in diameter, containing mercury fulminate, traversed by a minute platinum wire. The explosion of the first cartridges was deemed to be sufficient to explode all the others in the hole, and the result has been, so far as can be known, consistent with this theory. It will be understood, of course, that the electrician removed each peg as he went, replacing it with an exploding cartridge. All the wires were collected and grouped into two cables which led directly to the batteries. No details as to the construction of the batteries finally adopted after much speculation and experiment, have as yet reached this country. A large number of holes were opened to less than the proper

depth, either because water was encountered in quantity, or hard veins of rock practically impenetrable by the drills were encountered. Into such borings, however, cartridges were stuck without any exploders, on the chance that they would go off in the general concussion.

No tamping of any kind was employed. But before the charges were exploded water was admitted to fill the workings, and this proved quite sufficient for every purpose. The holes were bored in the columns at distances of about two feet apart vertically, while numbers of cartridges were inserted in the roof, as close as possible to the heads of the pillars, to ensure the destruction of these last for a couple of feet at all events. The descent of the superincumbent mass once begun, would effect the rest.

The charges are arranged in what are termed battery groups, there being 184 of these groups of twenty charges each. The priming fuse is the ordinary electric fulminate of mercury exploder. The wires of a group were connected each to each. A short distance from the mine a strong bomb-proof was built in which the batteries were placed. These batteries consisted of 960 bichromate of potash cells, the zinc and carbon plates opposing an area of forty square inches each to the fluid. These cells were divided into twenty-three batteries of about forty-two cells each connected for intensity. Each battery exploded eight groups of holes or 160 fuses in continuous circuit. The wires from the batteries to the charges were insulated by a gutta percha coating, and placed in wooden boxes to prevent abrasion.

The circuit closer consisted of twenty-three brass pins which were to drop simultaneously into twenty-three mercury cups, thus closing each battery circuit at the same instant. The plate containing the brass pins was held by a fuse or torpedo, which was exploded by a separate battery situated at a safe distance. This circuit was finally closed by Gen. Newton's little three year old daughter.

The spectacle—as a spectacle—was not very grand. There was a very moderate report, and not a very considerable upheaval of the water. But it is interesting to note that the underground tremor was felt as a mild earthquake for some distance. The latest reports on the subject are to the effect that soundings taken by General Newton show that all that was intended has been accomplished.

ORDNANCE AND NAVAL.

THE NEW UNITED STATES STEAMER TRENTON.—The Trenton is said to be one of the finest and probably fastest vessels in the naval service, being fitted with compound engines, two low-pressure and one high-pressure cylinders, the former seventy-eight inches in diameter, and the latter 58½ inches in diameter, and all of four feet stroke, with an indicated 3500-horse power. She has eight cylindrical boilers, twelve feet in diameter, and ten feet three inches long, with 510 feet of grate surface, and 12,000 feet of heating surface. The propeller is the Hirsch four-bladed screw, 19.5 feet diameter, and twenty-eight feet mean pitch. The length of the vessel is 253 feet between perpendiculars, forty-eight feet beam, and twenty-three feet depth of hold from main deck. She is to be full ship rigged, and will be armed with eleven eight inch rifled guns. She is also to be a ram, being provided with a prow extending eight feet beyond the bow. The vessel, of 2300 tons burden, was designed by Naval Constructor Isaiah Hanscom. Heretofore it has been difficult to make the sailors comfortable in cold weather, owing to the danger of the heating apparatus, from bursting tubes, and the necessity of shutting off the steam at night in order to sleep. This annoyance has been overcome by adopting a new open base radiator, which is so arranged that water can never accumulate in the pipes from condensation causing unequal expansion and frequent bursting of the tubes. The Trenton will be capable of going at a mean speed of thirteen knots, and will be, it is expected, one of the most formidable cruisers of the navy.—*Scientific American.*

A FORMIDABLE WAR ENGINE.—The United States torpedo boat Alarm, now lying at the navy yard, has an armament consisting of one fifteen inches Dahlgren gun, rigged to fire from the bow; four Gatling guns that are rigged on the rail and can be shifted from side to side in less than one minute, and three torpedo bars, one on each side of the bow and one running out of the prow, which extends forty feet ahead of the bow—twenty-five feet of it being under the surface of the water. The prow is so constructed that it can be used as a ram when necessary, and is formed of iron four inches and six inches thick, in such form that it is perfectly buoyant, and instead of tending to drive the vessel's bow nose under a heavy sea, has a stronger tendency to keep it free. The two bow torpedo bars are each fifteen feet in length, and are so arranged that they can be run inside of the vessel to ship the torpedoes, and run out again to discharge them. They pass through the side of the vessel in a watertight sleeve, about three feet below the water line, and the orifices being filled with watertight valves there is no fear of any flow of water from the outside. The prow torpedo bar is worked in the same manner as the others, but can be run out twenty feet beyond the point of the prow, so that the torpedo will actually be discharged sixty-five feet from the bow of the vessel. The guns and torpedoes can be fired by electricity, governed by a keyboard in the pilot house, and the battery is strong enough to discharge the gun and explode the torpedo simultaneously. The latter can also be exploded by concussion. Both gun and torpedo bars can be operated wholly by steam if required, and so instantaneous is the application that much time is saved over the old method of working everything by hand. Each of the Gatling batteries is capable of firing 400 discharges a minute.—*New York Commercial.*

BOOK NOTICES.

PLUMBING. By WILLIAM PATON BUCHAN. London: Crosby, Lockwood & Co. For sale by D. Van Nostrand. Price $1.20.

A book for the artisan, but containing valuable hints for the householder.

The modern methods of house drainage form a proper supplement to the treatise on plumbing.

Although a medium sized volume of the famous Weale's Series, it contains two hundred and seventy-nine illustrations.

THE FLEETS OF THE WORLD—THE GALLEY PERIOD. By Commodore FOXHALL A. PARKER. (In Press.) New York: D. Van Nostrand.

This is not a work on Naval Architecture, but a readable historical sketch of the primitive and transition states of sea-going vessels, and the maneuvres of which such rudimentary forms were capable.

The author is an officer of forty years' service in the navy, and has exhibited a professional interest in his subject. The description of ancient sea-fights is especially vivid and masterly, and the careful reader will not fail to notice, that although in graphic detail it is hardly surpassed by the record of modern events by the inevitable reporter, it is really the work of a careful historian, who has employed legitimate means to clearly interpret the facts he has gathered.

THE ELEMENTS OF GRAPHIC STATICS. By KARL VON OTT. Translated from the German by GEORGE SYDENHAM CLARKE. New York and London: E. & F. N. Spon. For sale by D. Van Nostrand. Price $2.00.

Graphic statics is growing in favor. The little work of Von Ott is more rudimentary than the other treatises in English on this science.

The translator has omitted a short chapter of graphic arithmetic, which is found in the German; otherwise, the excellencies of the original, and they are many, are reproduced in the translation.

The little work is in three parts; the first dealing with methods of graphic solution, the second with framed structures, and the third with the strength of materials.

The diagrams are distributed through the text.

THE THEORY OF COLOR IN ITS RELATION TO ART AND ART INDUSTRY. By Dr. WILHELM VON BEZOLD, translated from the German. By S. R. KOEHLER. Boston: L. Prang & Co. For Sale by D. Van Nostrand. Price $5.00.

This treatise is based on the science of optics, and ignores the rules deduced from the theories of artists, or rather writers upon art. Of these latter several have promulgated rules for observance by colorists, which rules were well enough in their way, but when the writers undertook to establish a rigorous classification of colors, tints, hues, etc., some remarkable differences appeared among good authorities, and much confusion in our text books has been the result.

The illustrations of the book are excellent especially the colored lithographs.

An introduction by Prof. Pickering sets forth the value of the work in strong terms of approbation.

All students and teachers of physical science need the book.

SANITARY WORK IN THE SMALLER TOWNS AND VILLAGES. By CHARLES SLAGG. London: Crosby Lockwood & Co. For Sale by D. Van Nostrand. Price $2.50.

Notwithstanding the abundance of new literature, on sanitary subjects, this latest contribution is not in excess of the public needs. In the new crusade against uncleanliness, cities were, for obvious reasons, the first object of attack; but it is well known that many customs capable of engendering the so-called filth diseases, have their origin in the country. To such customs Mr. Slagg gives his attention.

The work is divided into three parts, as follows: Part I, Some of the more common forms of nuisance and their remedies. Part II, Drainage. Part III, Water Supply. The author's style is exceptionally clear and concise and his book deserves a wide circulation.

NOTES ON BUILDING CONSTRUCTION. Part II. London, Oxford & Cambridge: Rivingtons. For Sale by D. Van Nostrand. Price $3.50.

Readers who have become familiar with Part I of this exceedingly practical work will gladly learn of the appearance of Part II.

The author's plan comprehended an aid to students who designed to become builders, as well as a valuable hand book for architects engaged in directing practical operations.

The subjects treated in the present volume are: Brick Work and Masonry; Timber Roofs; Roof Coverings; Compound Beams; Joinery; Stairs; Riveting; Iron Roofs; Plasterers Work; Painting; Paper-hanging and Glazing.

Some of these sections are supplementary to those bearing the same title in the first volume.

The books are well illustrated; but much of the writing is hastily done, and anything like logical arrangements of subjects seems to have been ignored.

TRAITEMENT PRATIQUE DES VINS. Par RAIMOND BOIREAU. Paris: E. Lacroix. For sale by D. Van Nostrand. Price $2.00.

This work is much less cumbersome than the English works that promise the same information, and is withal more thoroughly practical. It is a book for the wine manufacturer. The minutest details of the commonest processes are described and illustrated with diagrams. Fig. 72 is a common and ugly form of pitcher. Fig. 89 is a corkscrew of an old pattern. Figs. 17, 18 and 22, are garden watering-pots. Most of the 125 cuts, however, are important aids to the descriptive text, although the writer seems to have prepared his work for readers who have little or no inventive powers, at least in the direction of mechanical operations. Excess of plain directions is a fault easily tolerated in such works, and is quite as acceptable as the chemical formulas usually found in books on wines.

RECUEIL D'EXERCISES SUR LA MECANIQUE RATIONELLE. Par A. DE SAINT GERMAIN. Paris: Gauthier Villars. For sale by D. Van Nostrand. Price $1.40.

This work is in three parts, devoted respectively to Statics, Cinematics and Dynamics.

Although employing the Calculus, the work can hardly be called difficult to students who have made a fair beginning in Analytic Mechanics.

THE ELEMENTS OF ANALYTICAL MECHANICS. By DE VOLSON WOOD, A. M., C. E. New York: John Wiley & Sons. For sale by D. Van Nostrand. Price $3.00.

The author of this new work is well known as a writer, a civil engineer, and as an instructor in one of the leading technical schools. The work before us combines the excellencies which one is entitled to expect from such a source.

Prof. Wood's long experience as an instructor has made him fully aware of the difficulties which the learner must encounter in this branch of applied mathematics. His experience as a practical engineer has rendered him quite as familiar with the ultimate objects of such training. The result, as represented in the Analytical Mechanics, is a book which combines qualities, not heretofore presented in the same treatise.

The practice in our best schools has been of late to employ two separate treatises for instruction in Mechanics, the one purely Analytical in character, and another quite as distinctly practical; and out of these a course was *picked* for the student. The necessity for such a plan of teaching is, we judge, entirely superseded by this new treatise. Analytical processes are thoroughly taught, and the end to which they are practically directed is fully presented.

As a preparation for the higher treatises of Mechanics or Astronomy, we know of nothing better.

THE MOON, AND THE CONDITION AND CONFIGURATIONS OF ITS SURFACE. By EDMUND NEISON, F. R. A. S. London: Longmans, Green, & Co. For Sale by D. Van Nostrand. Price $15.00.

The greater portion of the material forming the present work is new, and has been mainly derived from eight years constant selenographical observations. These were principally made with an excellent six inch equatorial, of fine definition. They include a series of several hundred lunar sketches and drawings, which served as material for revising a considerable portion of the great lunar map of Beer and Madler. For this purpose use has also been made of a collection of some hundred lunar sketches made of late years by different astronomers, and which from time to time have been sent to the author.

As it has been in general assumed, entirely without any foundation, that the Moon can have no atmosphere of any appreciable importance, it has been considered desirable to point out how entirely baseless this view is, and to show not only that the Moon may possess an atmosphere relatively little inferior to the Earth's, but also that the entire evidence we possess on this subject is strongly favorable to the Moon actually possessing such an atmosphere.

To the mathematical portion of Selenography much has been added, including nearly 400 measures of the position of points of the first order; the determination from some 200 measures of nearly 100 points of the second order; a considerable number of measures of the dimensions of different formations, and a number of determinations of the height of different lunar mountains. Most of Madler's estimations of brightness have been revised, and a considerable number of new objects have had their brightness determined.

COURSE IN DESCRIPTIVE GEOMETRY AND STEREOTOMY. By S. EDWARD WARREN, C. E., of the Massachusetts Institute of Technology. New York: John Wiley & Sons. For sale by D. Van Nostrand.

1. Elementary Free-Hand Geometrical Drawing.
2. Elementary Plane Problems.
3. Drafting Instruments and Operations.
4. Elementary Projection Drawing.
5. Elementary Linear Perspective.

The above series makes up the elementary course, and is supplemented by a like number of volumes extending to the higher branches of the science.

The first series is admirably adapted for the use of students who must work without an instructor. The methodical arrangement of this author is a more efficient aid to learning than the elucidations of the average teacher of drawing.

The first of the above series is of value chiefly for its suggestions for rudimentary practice, but, many who are beyond this stage of learning would do well to have the Eighth Chapter at hand for reference when *lettering* maps or drawings.

Elementary Plane Problems is a book for every teacher of Geometry. There is no better stimulus to a student of plane geometry than problems selected with reference to his advancement.

Drafting Instruments and Operations affords useful hints as to the proper use of the implements, and some altogether indispensable ones about the manipulations of inks and colors.

Elementary Projection Drawing may be profitably used at once by students who have enjoyed a slight course of elementary geometry under an instructor; and it also presents enough of the subject to answer the general purposes of the artisan. The subject is presented in five divisions: 1. Elementary Projections; 2. Details of Construction in Masonry, Wood and Metal; 3. Rudimentary Exercises in Shades and Shadows; 4. Isometrical and Oblique Projections; 5. Elementary Structural Drawing. This book has reached its fourth edition.

Elementary Linear Perspective: While the exact science is fully presented here, the technicality will not seem too strict to those who study it for its application to pictures in the

general way. The hints on aerial perspective appropriately follow the scientific lessons.

For testimony in reference to the excellence of Prof. Warren's method as an instructor, we may refer with confidence to Prof. Warren's former pupils. They are to be found among engineers and architects throughout the country.

MISCELLANEOUS.

An improvement in safety lamps has been devised by M. A. B. Boullenot, sen., of Paris. It consists in replacing the safety-lamps usually employed in mines containing fire-damp by lamps supplied with air from outside the mine. Fixed pipes are carried down the mine, and branches are led into all the workings Through these compressed air is forced from the surface by air-pumps, and the improved lamps are screwed to the air pipes by couplings with stopcocks. The cylinder which incloses the flame is protected by a cage, and the products of combustion pass off through two pieces of wire-gauze. The match for lighting the lamp is inserted through a spring clip, ignited within the lamp and cannot be withdrawn until extinguished.

Innocuous Glaze for Earthenware.—Apropos of Dr. Richardson's remarks in his recent lecture, it may be interesting to note that M. Constantin, a chemist and druggist at Brest, is stated to have succeeded in making a harmless glaze for common earthenware, destined to replace the lead glazes which have hitherto been employed, and which possesses the great drawback of inducing more or less rapid poisoning. By the year 1872 M. Constantin had produced glazes which were not, so to say, dangerous, inasmuch as but a very small portion of lead entered into their composition. His mixture consists of silicate of soda, with the addition of powdered silex and a very small quantity of minimum. Subsequently to the year 1872 the glazes tried and approved of in the Lanilis pottery, near Brest, have contained no trace of lead. One of the two recipes adopted is as follows :—

100 parts of silicate of soda,
15 " powdered quartz,
25 " Meudon chalk ;

and the second is the same, but with the addition of ten parts of borax. The latter substance renders the glaze more fusible, as well as more brilliant, so that it requires a less strong fire than that according to the former recipe. The articles can be colored by copper for green, and manganese for brown.

Electric Light.—Experiments were made at Paris recently, before M. Baron, Director of the Electric Telegraph, on a new system for dividing the electric light. A single generator has fed with an admirable regularity not less than eighteen lamps, having each a power equal to 100 gas-jets. The effect was wonderful, and the apparatus will be tried shortly at the Lyons railway terminus. The principle is very simple, and was discovered by a working shoemaker. The current derived from a Gramme machine, slightly modified, is sent to a second machine, which rotates before forty-eight electro-magnets, four of these electro-magnets having a force sufficient to give a light equivalent to 100 gas-jets. Twelve electric lamps can be fed at any distance. By a very simple commutator any number of these twelve lamps can be grouped together, so that one, two, or more can be set in the same apparatus. Twelve working on the same point give a real burning sun. The force required for working both machines (the prime mover and the distributor) is derived from a four horse-power steam-engine. The experiments at the Lyons railway will be tried with sixteen lamps and an engine of from six to seven horse-power. The light will be equal to 1,600 gas-jets.—*Nature.*

Manufacture of Dynamite.—M. Sabrero the discoveror of nitro-glycerine, has communicated to the Academie des Sciences the results of some experiments which he thinks may be useful to manufacturers of dynamite.

While acknowledging the importance of M. Nobel's idea of giving to nitro-glycerine the consistency of a solid body by causing it to be absorbed by a silicious substance, so as to be more easily employed in mines, M. Sabrero has always been struck with the frequent occurrence of explosions in dynamite factories. He has often thought that these accidents, the details of which are very imperfectly known, may be caused by the manipulations which take place, either in preparing the paste of nitro-glycerine and the absorbent substance, or in moulding and compressing the paste for giving it the form of cartridges,—compression and friction against hard substances are so many causes which easily bring about an explosion of nitro-glycerine.

It seemed to M. Sabrero that these causes of danger might be avoided by modifying the manufacture of dynamite in the following manner:—The silicious substances, of the nature of *Kiesel-guhr*, &c., although only slightly plastic, are capable of being moulded after moistening with a little water, and take a consistency which is not inferior to that of dynamite cartridges. He made some cylindrical cakes with Santa Fiora fossil metal, which after being dried at 100° Cent. (212° Fahr.), to get rid of the water, were plunged vertically into the nitro glycerine, so as to become saturated therewith.

The experiments to determine the quantity of nitro-glycerine which cakes were capable of absorbing, were not made with the liquid itself for fear of accident, but with olive oil, which is nearly of the same consistency.

The author is convinced that dynamite with seventy-five per cent. of explosive substance, as is generally required, may readily be obtained by his process; while at the same time, all violent pressure or friction is avoided. The cakes, after leaving the bath of nitro-glycerine, have only to be placed to drain, and then wrapped in paper, when they are ready for use.